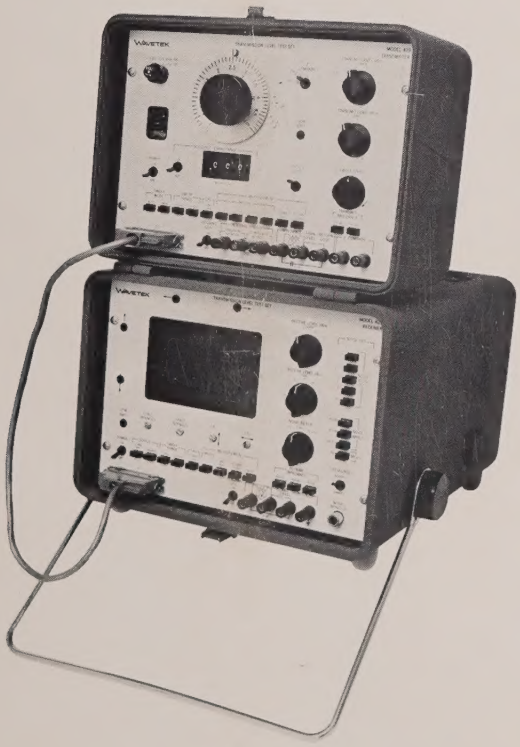
INSTRUCTION MANUAL

MODEL 420
TRANSMISSION LEVEL
TEST SET



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MODEL 420
TRANSMISSION LEVEL
TEST SET

WAVETEK
Box 651, San Diego, Calif., 714-279-2200

12/73

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TABLE OF CONTENTS

Section		Page No.
1.	PURPOSE AND SCOPE	1
2.	TRANSMITTER DESCRIPTION	3
3.	RECEIVER DESCRIPTION	7
4.	PREPARATION	11
	A. Setup	11
	B. Calibration	12
	C. Battery Use and Care	12
	D. Circuit Under Test	12
5.	MEASUREMENTS	15
	A. Received Level Measurement	15
	B. Transmission Loss Measurement	17
	C. Impedance Measurement	19
	D. Impedance Comparison	21
	E. Two-Wire Return Loss Measurement	23
	F. Four-Wire Return Loss Measurement	25
	G. Cable Length Measurement	27
	H. Noise Measurement (Noise Option)	31
6.	GENERAL CONSIDERATIONS	33
	A. Battery	33
	B. Receiver Off Hook	33
	C. Ground Connections	33
	D. Transmission Level	33
	E. Circuit Termination	34
	F. Echo Suppressors	35
	G. Alternating Current Signalling	36
	H. Transmission Loss and Loss Frequency Measurements	36
	I. Internal Hybrid (Impedance Bridge) Use	36
	J. Return Loss Measurements	37
	K. Noise Measurements (Noise Option)	38
7.	REFERENCES	41
	BIBLIOGRAPHY – Table A	42
	BELL SYSTEM PRACTICES – Table B	43

OPTION INDEX

	Paragraph
Battery Power	4.C.
Noise Measurement	3.12, 3.23 thru 3.30, 5.H., 6.K.
Impedance Comparison	2.15, 5.D.
Buildout Capacitance	2.17

TRANSMITTER

RECEIVER

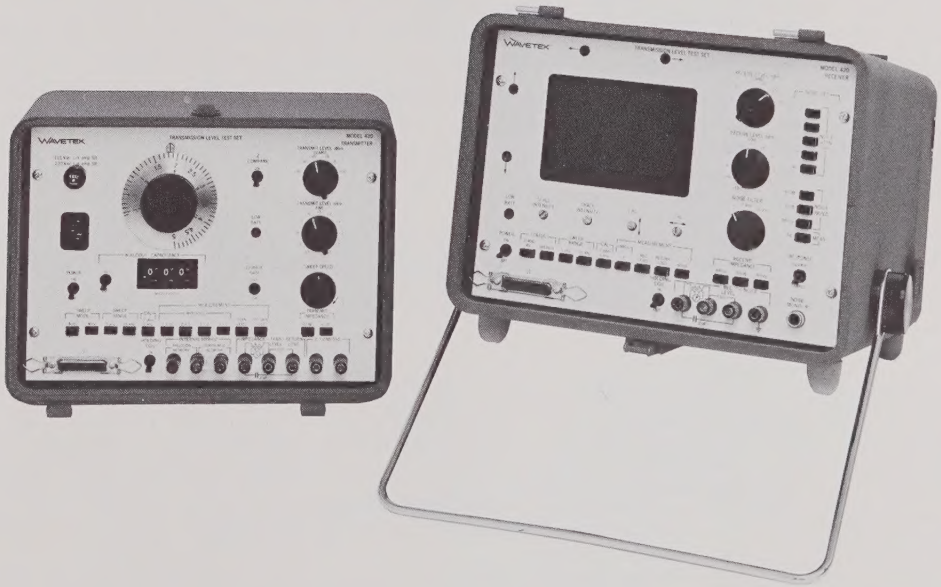


Figure 1. Model 420 Transmission Level Test Set

MODEL 420 TRANSMISSION LEVEL TEST SET
DESCRIPTION AND USE

1. PURPOSE AND SCOPE

1.01 This manual describes the Wavetek Transmission Level Test Set Model 420, and gives methods for using it to measure:

- Impedance
- Transmission Levels
- Transmission Losses
- Return Loss, Balance
- Cable Length
- Noise (Noise Option)

1.02 The Model 420 consists of two major components: a transmitter, and a receiver (Fig. 1). The rear section of the receiver is its power supply.

1.03 The transmitter is a voltage controlled oscillator, which transmits from 50 to 15,000 Hz. The output level can be set in 1 dB steps from −50 dBm to +10 dBm into either 600Ω or 900Ω. The frequency may be set to a single fixed value, swept manually, or swept automatically. The sweep rate may be varied from 10 to 30 sweeps per minute, and the frequency may be swept from 50 to 5000 Hz, or from 150 to 15,000 Hz. The transmitter also contains a very sensitive hybrid network that serves as an impedance bridge in the return loss mode.

1.04 The receiver is a cathode ray oscilloscope arranged to show impedance, level, or return loss on the vertical scale as a function of frequency on the horizontal scale. When the received signal varies in frequency, the spot moves horizontally to indicate the frequency, and vertically to indicate the corresponding level or impedance. The result is a graph of the measured level vs frequency.

1.05 The receiver with the noise measurement option measures noise as the weighted average power over the voice band in accordance with the standard weightings designated as C-Message, 3 kHz Flat, and 15 kHz Flat. For this measurement, the spot on the screen moves vertically to indicate the noise power without respect to frequency. The spot is read on the vertical scale in the same way as the needle on an ordinary meter is read. Persistence and intensity of the trace make it easier to estimate the average value of noise.

1.06 The functions of controls, jacks, and indicators on the front panels of the transmitter and receiver are described herein, and methods of use follow. This manual is a practical guide in the use of the instrument. It does not develop the theory underlying the various measurements.

1.07 *Options:* The Model 420 may have any of the following optional equipment. The options are noted as such throughout the manual.

(1) Noise Measurement

(2) Battery Power

(3) Impedance Comparison

(4) Buildout Capacitance

(5) Rack Mount

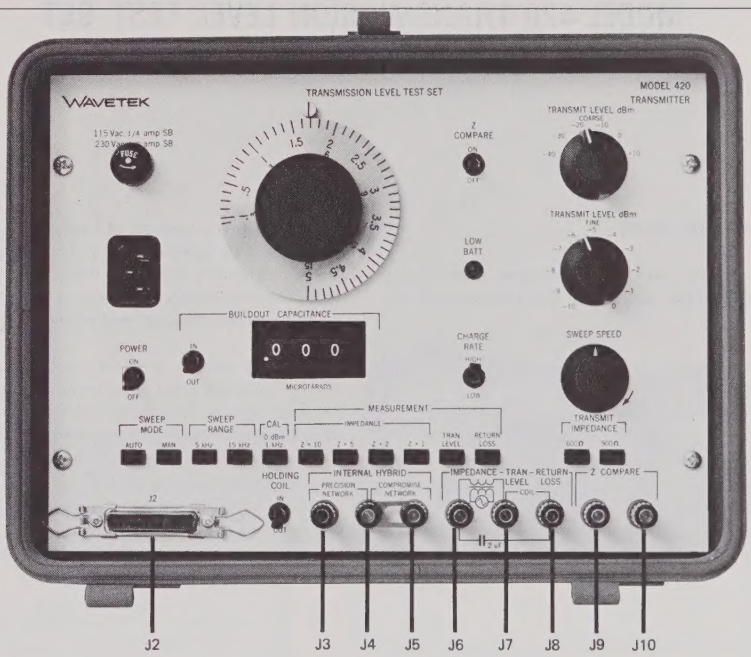
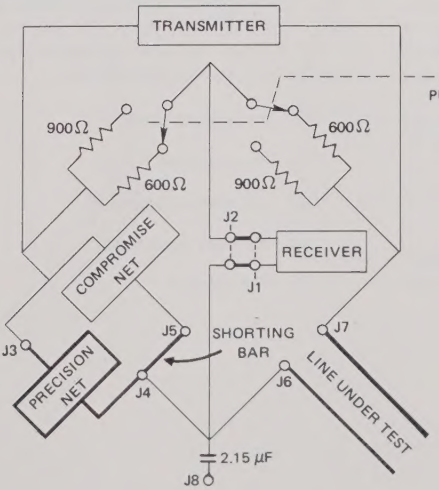


Figure 2. Transmitter Front Panel



Notes:

1. Precision net and heavy black line connections are external to the Model 420.
2. Refer to Figure 2 for jack number location on the transmitter.
3. The 2.15 µF capacitor is a compromise between the two standards of 2.14 µF and 2.16 µF. This compromise produces an error of less than ±0.1% in expected readings.

Figure 3. Internal Hybrid Arrangement for Two-Wire Return Loss Measurement

2. TRANSMITTER DESCRIPTION

2.01 The principal components of the transmitter (Fig. 2) are:

(1) Voltage Controlled Sweeping Oscillator

(2) Output Attenuator

(3) 600Ω and 900Ω Terminating Impedances

(4) Setup Switches

(5) Hybrid with Compromise Network

(6) Jacks for Connecting the Transmitter to the Receiver and Test Apparatus

(7) Power Supply for 115 Vac or 230 Vac, 40 to 400 Hz with Optional Rechargeable Battery

(8) One Milliwatt, One Kilohertz Calibration Power

2.02 *Sweep Range, Frequency, Sweep Mode and Sweep Speed Controls:* The oscillator frequency ranges from 50 to 5000 Hz, or from 150 to 15,000 Hz, depending on the setting of the SWEEP RANGE. With the SWEEP MODE switch set to MAN, the FREQUENCY dial controls the frequency of the oscillator. The outer circle of figures gives the frequency in the 5 kHz range, the inner circle, in the 15 kHz range. With the SWEEP MODE switch set to AUTO, the FREQUENCY dial is disabled, and the oscillator automatically sweeps continuously from the lowest frequency of the range to the highest and returns. The SWEEP SPEED knob controls the sweep rate from about 10 to 30 sweeps per minute.

2.03 *Transmit Level Switches:* The two switches TRANSMIT LEVEL dBm COARSE, and TRANSMIT LEVEL dBm FINE control the output level of the transmitter. The output level in dBm is the algebraic sum of the settings of the two switches. For example, with the COARSE switch set at −10 dBm and the FINE switch set at −3 dBm, the output from the oscillator is −13 dBm.

2.04 *Transmit Impedance Buttons:* The TRANSMIT IMPEDANCE switch matches the impedance of the transmitter to a 600Ω circuit or to a 900Ω circuit. It does this by changing the internal impedance of both the oscillator, and the internal hybrid, and by changing the oscillator voltage. The change in oscillator voltage is necessary to assure that the TRANSMIT LEVEL and the output power are correct for the impedance selected.

2.05 *Impedance Measurement Buttons:* The MEASUREMENT switch consists of six pushbuttons, four of which are for IMPEDANCE measuring. When operated, each multiplies the reading of impedance on the receiver screen by the factor shown on the transmitter panel. In the impedance mode, the external connections and controls of the receiver are disabled, and the receiver is connected thru the J1/J2 interconnecting cable to the transmitter. The transmitter applies a constant current to the circuit under test and the receiver cathode ray tube beam is deflected by the voltage across the impedance. When measuring impedance, it is preferable to operate the set at the lowest convenient multipliers.

2.06 *Transmit Level Measurement Button:* The TRAN LEVEL button of the MEASUREMENT switch separates the transmitter from the receiver, and arranges the transmitter to send test power into a two-wire line. This mode is used for straightforward measurements of the loss-frequency characteristics of a telephone circuit between two-wire points in the circuit, or in either direction on a four-wire circuit. It is also used to measure return loss at the four-wire side of the hybrid coil, or network in the circuit or apparatus under test.

2.07 *Return Loss Measurement Button:* The RETURN LOSS button of the MEASUREMENT switch sets up the Model 420 as a very sensitive impedance bridge which compares the line or apparatus under test with a standard compromise network of either 600Ω or 900Ω depending on the setting of the TRANSMIT IMPEDANCE switch. The impedance bridge is in the form of a hybrid network as illustrated in Fig. 3. The circuit under test is connected to one side of the hybrid (the equivalent of the line connection of a hybrid coil); the internal compromise network or an external precision network is connected to another side (equivalent to the net connection of a hybrid coil); the receiver is connected across the hybrid to terminals that correspond to the transmitting connection; and the transmitter is connected across the remaining terminals, which correspond to the receiving side. In this arrangement, the RECEIVE LEVEL subtracted algebraically from the TRANSMIT LEVEL gives the return loss.

2.08 *Jack J2:* Jack J2 connects the transmitter to the receiver and contains a power interlock; **therefore, the J1/J2 cable or the jumper plug must be plugged into J2 for transmitter operation.**

2.09 *Internal Hybrid Jacks:* INTERNAL HYBRID jacks connect to the network side of the internal hybrid (Fig. 3). J3 and J4 are the two junctions in the hybrid bridge to which the balancing arm is connected. A compromise network is connected internally between J3 and J5. The shorting link between J4 and J5 connects the compro-

mise network in the balancing arm of the hybrid bridge. The internal hybrid is used for two-wire return loss measurements in which a two-wire circuit is balanced against either the internal compromise network, or an external precision network. This internal hybrid also serves as a sensitive impedance bridge for direct measurement of impedance in terms of its resistive, capacitive, and inductive components. Some applications are given in Paragraph 6.1.

2.10 *Impedance / Transmit Level / Return Loss / Z Compare Jacks:* TRAN LEVEL – RETURN LOSS are for external connection to the circuit under test. Jacks J6 and J7 connect directly to the input transformer and the impedance matching network controlled by the TRANSMIT IMPEDANCE buttons. Jacks J7 and J8 connect to the transformer thru a capacitor* which will block dc and avoid saturating the transformer, which would affect the measurement. The presence of the capacitor does not affect measurements noticeably at frequencies within the pass-band of voice-frequency telephone circuits. It should be used when dc is present on the circuit under test. J9 and J10 (Z Comparison Option) are used to connect the line under test when comparing its impedance characteristics with those of a model line connected to J6 and J7. On models without the Z comparison option, there is, in addition, a ground connector; its purpose is to bring ground in the Model 420 to the same potential as the ground of the circuit under test. This minimizes the effects of common mode potentials.

2.11 *Power and 115 V/230 V Switches and Fuses:* The power supply receives ac from 115 V or 230 V mains at 50 to 400 Hz thru the three-pronged connector just to the left of the FREQUENCY dial. A slide switch on the back of the chassis arranges the set for one supply voltage or the other; remove the chassis from the case for access. Use a screwdriver to slide the switch if the indicated voltage is wrong. Fuses for + and – 15 Vdc are also located on the back of the chassis.

2.12 The front panel FUSE protects the set against excessive current or voltage from the mains.

2.13 *Calibration Button:* When pressed, the CAL button sends 1 milliwatt of power at 1000 Hz to the receiver for receiver calibration. **This power also appears at the output jacks J6 and J7 of the transmitter; these jacks must be free of any connections during calibration.** Operation of any one of the MEASUREMENT buttons releases the CAL button.

2.14 *Charge Rate Switch and Low Battery Lamp (Battery Option):* With the power cord connected, the internal battery (option) is being charged by the power supply for either LOW or HIGH charge. The switch is normally left on HIGH and the battery recharges in about 14 hours. The LOW charge rate provides a trickle charge to the battery and is used when the set is stored for extended periods of time. Continuous charge at the HIGH rate will not harm the battery. The LOW BATT lamp flashes when the battery has energy left for about half an hour of operation. The POWER switch connects the transmitter to the dc power supply when ON and disconnects it when OFF. The POWER switch does not disconnect the ac from the internal power supply, so the battery charges even with the POWER switch OFF.

2.15 *Z Comparison Switch (Z Comparison Option):* Impedance (Z) comparison is done in the AUTO SWEEP MODE only. When the Z COMPARE switch is OFF, there is no Z comparison; when the switch is set on IDENT (not shown in Fig. 2), the J6/J7 output is a modulated, low-to-high frequency sweep, which causes the characteristic impedance curve of the line connected to J6/J7 to be a dotted curve on the display. The output of J9/J10 is an unmodulated, high-to-low frequency sweep, which causes the characteristic impedance curve of the line connected to J9/J10 to be a solid curve on the display. Therefore, as the transmitter output sweeps the frequency range up and down, the impedance curves of the two lines connected to the transmitter are displayed on the screen, one as a solid curve and the other as a dotted curve. When the switch is set to ON, both curves are solid.

2.16 *Holding Coil Switch:* This switch allows a telephone line under test to be seized by flipping the HOLDING COIL switch to IN. When using the holding coil, the transmission line must be connected to terminals J7 and J8 to block the dc placed on the line.

2.17 *Buildout Capacitance In/Out Switch and Thumbwheel Switch (Buildout Capacitance Option):* The IN/OUT switch connects the BUILDOUT CAPACITANCE across the PRECISION NETWORK terminals J3 and J4 for use in the internal hybrid (Fig. 3) or external use thru J3 and J4. The thumbwheel switches allow the capacitance to be varied from 0.001 μF to 0.999 μF ±1%.

* The capacitor is 2.15 μF ±1%, a compromise between the two standards of 2.14 μF and 2.16 μF. This compromise produces an error of less than ±0.1%.

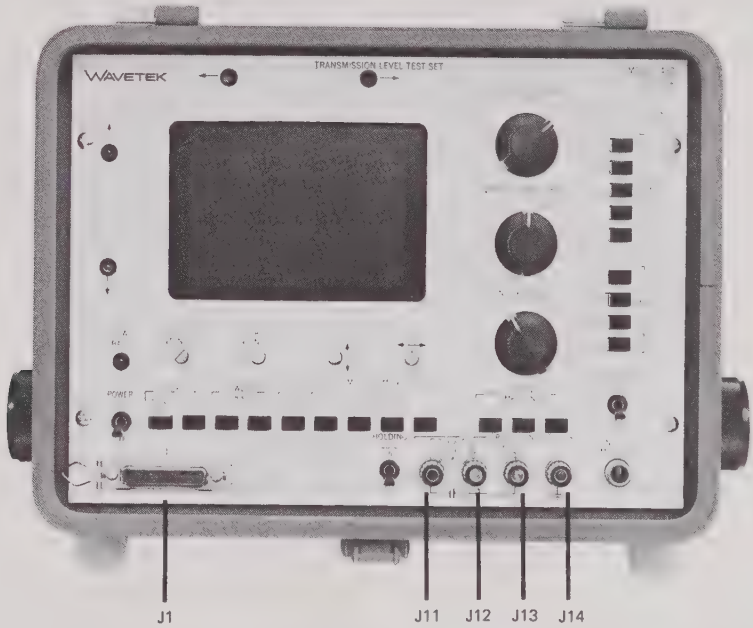


Figure 4. Receiver Front Panel

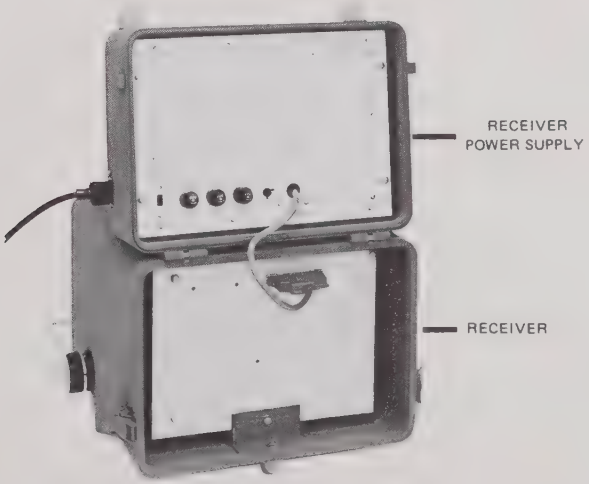


Figure 5. Receiver Power Supply

3. RECEIVER DESCRIPTION

3.01 The principal components of the receiver are:

(1) Cathode Ray Tube

(2) Receive Level Attenuator

(3) Input Jacks

(4) Setup Switches

(5) Power Supply

3.02 Fig. 4 illustrates the receiver front panel, and Fig. 5 the receiver power supply front panel.

3.03 *Cathode Ray Tube, Scale Intensity, Trace Intensity, Off-Screen Lamp, and Calibration:* The tube has a long-persistence phosphor so that the shape of the traced curves can be easily observed. It has two graticules. One graticule has a logarithmic vertical scale graduated in dB; the other has a linear vertical scale graduated in ohms; the horizontal scale is linear and graduated in kilohertz on both graticules. The MEASUREMENT pushbutton automatically selects and lights the proper graticule; the unused graticule is not visible.

3.04 Four off-screen lamps indicate the electron beam location when it is off the screen.

3.05 The SCALE INTENSITY control is a screwdriver adjustment of the graticule illumination; TRACE INTENSITY controls the brightness of the spot on the screen. The two controls marked ↕ and ↔ position the spot at the intersecting 0 dB/1 kHz lines when calibrating the set; these adjustments are made with the CAL buttons depressed on the transmitter and receiver. These two adjustments comprise the entire calibration procedure.

3.06 *Status Buttons:* The STATUS buttons conserve battery power between measurements. Only the heater of the cathode ray tube remains on when the STAND BY button is depressed so that there is no warm-up delay when switched from STAND BY to OPERATE. The OPERATE button applies full power to the receiver components.

3.07 *Sweep Range Buttons:* The SWEEP RANGE buttons control the range of frequencies over which the receiver functions: 50 to 5000 Hz or 150 to 150,000 Hz. Both the transmitter and the receiver should be set to the same sweep range.

3.08 *Receive Level Switches:* The switches RECEIVE LEVEL dBm COARSE and RECEIVE LEVEL dBm FINE control the input attenuator for measurements of received level and return loss. The level in dBm of the signal being measured is the algebraic sum of the two attenuator settings and the deflection of the spot on the cathode ray tube.

3.09 For example, assume that you want to know the received level at 3000 Hz, and you observe the following:

RECEIVE LEVEL dBm

COARSE	−10 dBm
FINE	+ 4 dBm
Trace on screen at 3 kHz	− 1.5 dBm
Algebraic Sum =	− 7.5 dBm

3.10 When the off-screen lamp marked ↑ indicates that the beam is above the top of the screen, turn the RECEIVE LEVEL dBm COARSE switch counterclockwise; i.e., toward the positive dBm values, to bring it into view; and vice versa when the lamp marked ↓ indicates that the beam is off screen on the low side.

3.11 *Receive Impedance Buttons:* The RECEIVE IMPEDANCE buttons match the set to the impedance of the circuit under test. The 600Ω button terminates the circuit under test in 600Ω and measures the level across 600Ω. The 900Ω button terminates the circuit under test in 900Ω and measures the level across 900Ω. The BRIDG button selects 25,000Ω internal impedance for bridging across a circuit without terminating it in the set; in bridge mode the set is calibrated to read correctly the level in a 600Ω circuit. If a bridge measurement is made in a 900Ω circuit, the reading will be 1.8 dB too high; it should be reduced by this amount. For example, suppose that a −7.5 dBm reading had been taken in bridge mode on a 900Ω circuit. Then, it is corrected as follows:

Uncorrected Reading	−7.5 dBm
Correction for 900Ω	−1.8 dB
Corrected RECEIVE LEVEL	−9.3 dBm

3.12 *Receive Level/Noise and J1 Jacks:* Input to the receiver is thru the REC LEVEL – NOISE jacks, or thru J1 from the transmitter, depending on which MEASUREMENT button is operated. Jacks J11 and J12 connect directly to the input transformer and the impedance matching network controlled by the RECEIVE IMPEDANCE buttons (or the NOISE IMPED buttons in the noise option model). Jacks J12 and J13 connect to the transformer thru

a capacitor* which will block dc and avoid placing an on-hook condition on the circuit under test. The presence of the capacitor does not noticeably affect measurements at frequencies within the pass-band of voice-frequency telephone circuits. It should be used when dc is present on the circuit under test to avoid saturating the input transformer and upsetting the measurement. Think of J12 as the tip, and J13 as the ring side of the circuit.

3.13 Jack J14 is a ground connection; its purpose is to bring ground in the Model 420 to the same potential as the ground of the circuit under test. This minimizes the effects of common mode potentials.

3.14 When the IMPED or the RETURN LOSS button of the MEASUREMENT switch is operated, input to the receiver is via transmitter jacks and the connecting cable J1/J2.

3.15 Jack J1 connects the receiver to the transmitter and contains a power interlock; therefore, the J1/J2 cable or the jumper plug must be plugged into J1 for receiver operation.

3.16 *Impedance Measurement Button:* The MEASUREMENT switch consists of four buttons, one for each mode of measurement. The IMPED button connects the receiver across the terminals of the transmitter via the J1/J2 cable. The transmitter sends a constant current into the circuit under test so that the voltage across the circuit is a measure of the impedance of the circuit. The value of impedance is the deflection of the spot or trace on the screen of the receiver multiplied by the value of the IMPEDANCE button operated on the transmitter. For example, if the screen shows 250Ω at 3 kHz, and the transmitter has the Z X 5 button pressed, the impedance of the circuit under test is 250 X 5 = 1250Ω at 3 kHz.

3.17 *Received Level Measurement Button:* The REC LEVEL button arranges the receiver as an electronic voltmeter that is calibrated to read dBm in 600Ω, 900Ω, or bridge mode. In this mode, the receiver functions independently of the transmitter. The received level measured on a circuit under test is the algebraic sum of the deflection of the spot and the RECEIVE LEVEL attenuator switches.

3.18 *Return Loss Measurement Button:* The RETURN LOSS button connects the receiver as a detector across the internal hybrid (impedance bridge) in the transmitter for two-wire return loss measurements as shown schematically in Fig. 3. The return loss of the circuit being measured is the algebraic difference of the transmitted level minus the received level. The Model 420 is calibrated to account for the loss in the internal hybrid, so no correction is required for trans-hybrid loss.

3.19 *Power Switch and Power Cord:* The POWER switch connects the dc power supply to the receiver. The power supply box is attached on the rear of the receiver (Fig. 5). The power cord, when connected to the three-pronged connector in the back of the power supply box applies ac power to the power supply at all times, even when the receiver POWER switch is OFF.

3.20 *AC Line Voltage Switch and Fuses:* The AC LINE VOLTAGE switch located on the front panel of the power supply box arranges the power supply for either 115 volts or 230 volts, as required, to match the mains voltage. The fuses are on the ac line and the positive and negative dc supply for the receiver.

3.21 *Low Battery Lamp and Charge Rate Switch (Battery Option):* The LOW BATT lamp, located on the receiver front panel, begins to flash when 15 minutes or less of operating time remains in the battery.

3.22 When the ac power cord is connected, the receiver power supply CHARGE RATE switch at HIGH recharges the power supply battery in about 14 hours. The LOW rate is a trickle-charge for use when the set is stored for extended periods. Continuous charge at HIGH will not harm the battery. The receiver POWER switch does not disconnect ac from the power supply, so the battery will charge even with the POWER switch OFF.

3.23 *Noise Measurement Button and Noise Filter Switch (Noise Option):* The NOISE button of the MEASUREMENT switch arranges the receiver to measure electrical noise. Three different weightings are provided under control of the NOISE FILTER switch: standard C-message weighting; 3 kHz flat weighting; and 15 kHz flat weighting. The C-message weighting measures the noise on a circuit in terms of how much it would affect people talking on the circuit. The Model 420 indicates the noise level in dBrn, which is the power level in dB above one picowatt. One picowatt is −90 dBm; thus, 27 dBrn amounts to −63 dBm.

3.24 Requirements are usually stated in terms of the 0 TLP. If 27 dBrnC of noise power were measured at the +7 TLP (the receiving transmission level at the output of a multiplex channel), then, the equivalent level at the 0 TLP would be 20 dBrnC0. This means: 20 dB above one picowatt, C-message weighting, referred to the zero transmission level point in the circuit under test. Noise power is the weighted sum of power at all frequencies in the measured band.

* The capacitor is 2.15 μF ±1%, a compromise between the two standards of 2.14 μF and 2.16 μF. This compromise produces an error of less than ±0.1%.

3.25 *Noise Set Buttons (Noise Option):* The column of controls at the right hand side of the panel, marked NOISE SET, are only for noise measurements; they are disabled when any other measurement mode is selected. The NOISE ATTN dBrn buttons control attenuator pads of 5, 10, 10, 20, and 40 dB, as marked. When an attenuator button is depressed, the corresponding pad is in the receiving circuit. The noise level is the algebraic sum of the dB values of the buttons pressed, plus the deflection of the spot on the screen. Pressing an attenuator pushbutton switches it to its alternate state; if it was in, it pops out; if it was out, it stays in.

3.26 *Noise Impedance and Noise-to-Ground Buttons (Noise Option):* The NOISE IMPED buttons (600Ω, 900Ω, and BRIDG) arrange the set to properly terminate the line under test or to bridge across a terminated circuit in order to measure metallic circuit noise. The button MEAS – N_g arranges the receiver to measure noise to ground. In N_g mode, 40 dB must be added to the reading.

3.27 *Response Switch (Noise Option):* The RESPONSE switch arranges for a normal measurement, which closely follows the noise signal, or damped measurement, which restricts the speed of response of the reading.

3.28 The Model 420 indicates the noise level by the vertical deflection of its electronic beam, which has the desireable characteristics of:

(1) Lack of inertia, hence the beam follows the noise level precisely in time and indicates the maximum excursions, which is good for observing impulse noise.

(2) The intensity of the trace is a function of the time the beam spends at a given spot, hence the average value of noise is in the brightest part of the trace.

3.29 The damped response produces an indication that is equivalent to the damped indication of the Western Electric Type 3A Noise Measuring Set. With this response, a measurement by the Model 420 can be compared directly with requirements that are stated in terms of a reading of the WE Co. 3A or 3C Noise Measuring Set.

3.30 *Noise Monitor Jack (Noise Option):* The NOISE MONITOR jack is an output terminal from the noise amplifier in the receiver. Plug a monitor receiver in this jack to identify noise by listening to it.

3.31 *Holding Coil Switch:* This switch allows a telephone line under test to be seized by flipping the HOLDING COIL switch to IN. When using the holding coil, the transmission line must be connected to terminals J12 and J13 to block the dc placed on the line.

4. PREPARATION

A. Setup

4.01 The Model 420, closed for travel, is illustrated in Fig. 6. The set consists of three boxes: the transmitter, the receiver, and the receiver power supply. They are mechanically connected by slip hinges and toggle fasteners. They can be separated when necessary. The connecting cables and power cords are contained in space between the receiver and power supply. To set up the instrument for measurements, proceed as follows.

Figure 6. All Components Fastened Together for Carrying

4.02 *Receiver, Power Supply, and Connecting Cables:*

(1) Set the Model 420 on the transmitter end.

(2) Release the toggle fastener of the receiver power supply, and swing the power supply on its hinges.

(3) Take out the connecting cable, power cords, and other accessories.

(4) Set the AC LINE VOLTAGE switch to the proper value: 115 V or 230 V. (See Paragraph 4.03, Step 6.)

(5) Set the CHARGE RATE switch to HIGH (Battery Option).

(6) Inspect the three fuses to assure that none are blown.

(7) Test the power plug from power supply to receiver to assure that it is tightly locked.

(8) Close and fasten the power supply.

4.03 *Transmitter and Receiver:*

(1) Stand the set in a vertical position as in Fig. 6.

(2) Loosen the knobs for the support bail, and unscrew them until the bail is free to move.

(3) Flex the bail ends away from the case and adjust the position of the bail to any of several detents for the desired position of the set during measurement; tighten the knobs enough to hold the bail in the detent. Tip the set to rest on the bail.

(4) Release the transmitter/receiver fastener.

(5) Rotate the transmitter about its hinges until the transmitter case rests against the receiver case as in Fig. 7.

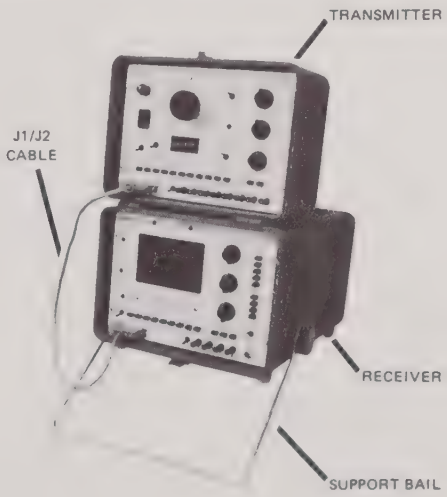


Figure 7. Transmitter Over Receiver Setup

(6) Both the transmitter and receiver are set for 115 V at the factory unless otherwise specified. If the receiver power supply AC LINE VOLTAGE switch required repositioning (see Paragraph 4.02), remove the four screws securing the transmitter chassis to its case and remove the transmitter chassis. Observe the line voltage switch and ensure that it is correctly positioned. Reinstall the transmitter chassis in the case.

4.04 *Transmitter Power:*

(1) Set the POWER switch to OFF.

(2) Plug in the J1-to-J2 cable to both the transmitter and receiver.

(3) Connect the power cord to the three-pronged connector in the front panel.

(4) Connect the power cord to the ac mains.

(5) Set the POWER switch to ON.

4.05 *Receiver Power:*

(1) Set the POWER switch to OFF.

(2) Ensure that the J1-to-J2 cable is plugged in to both the transmitter and receiver.

(3) Connect the power cord to the three-pronged connector in the back of the case.

(4) Connect the power cord into the ac source.

(5) Set the POWER switch to ON.

(6) Set the STATUS switch to OPERATE. Observe that the graticule lights.

B. Calibration

4.06 *Procedure:*

CAUTION

Ensure that J6 and J7 are free of any connections.

(1) On the transmitter, press the CAL button.

(2) On the receiver, press the CAL button.

(3) Observe the position of the spot on the screen; it should be at the intersection of the 0 dB and the 1 kHz lines.

(4) If the spot is at 0 dB and 1 kHz on the screen of the receiver, the set is in calibration; proceed with your measurements. If not, proceed to Step 5.

(5) Turn the slotted-head control marked ↕ to move the spot up or down to the 0 dB line on the screen if necessary.

(6) Turn the slotted-head control marked ↔ to move the spot left or right to the 1 kHz line on the screen if necessary.

(7) When the spot is adjusted to the intersection of the 0 dB and the 1 kHz lines, the set is in calibration; proceed with your measurements.

C. Battery Use and Care

4.07 If your Model 420 has the battery option, the transmitter and receiver each has its individual battery, battery charger, ac line cord, and controls. The transmitter battery is in the one-piece transmitter unit. The receiver battery is in the receiver power-supply box on the rear of the receiver.

4.08 The transmitter and receiver each has a CHARGE RATE switch and LOW BATT indicator lamp. The receiver CHARGE RATE switch is on the power supply box front panel.

4.09 When operating the Model 420 on the self-contained batteries, switch the STATUS of the receiver to STAND BY between measurements. This will conserve battery power and enable the receiver to operate all day without exhausting the batteries. The transmitter POWER may be switched OFF when a substantial time will elapse between measurements.

4.10 The transmitter LOW BATT lamp starts blinking when there are 30 minutes of operation left and continues to blink until the battery is completely depleted. The receiver lamp, which operates in the same manner, starts blinking when about 15 minutes of operation remain.

4.11 To charge the battery in either unit, turn the POWER switch OFF, connect the ac line cord and set the CHARGE RATE switch to HIGH. A depleted battery will be fully charged in 14 hours. The high charge rate will not harm the battery. The unit may be used while charging, and the POWER switch may be ON or OFF after installing the ac line cord; the battery will charge in either position. If the unit is being used regularly, the CHARGE RATE switch should be left on HIGH. When storing the set for extended periods, set the CHARGE RATE position to LOW. This is a trickle charge, which ensures full charge when the unit is to be used again.

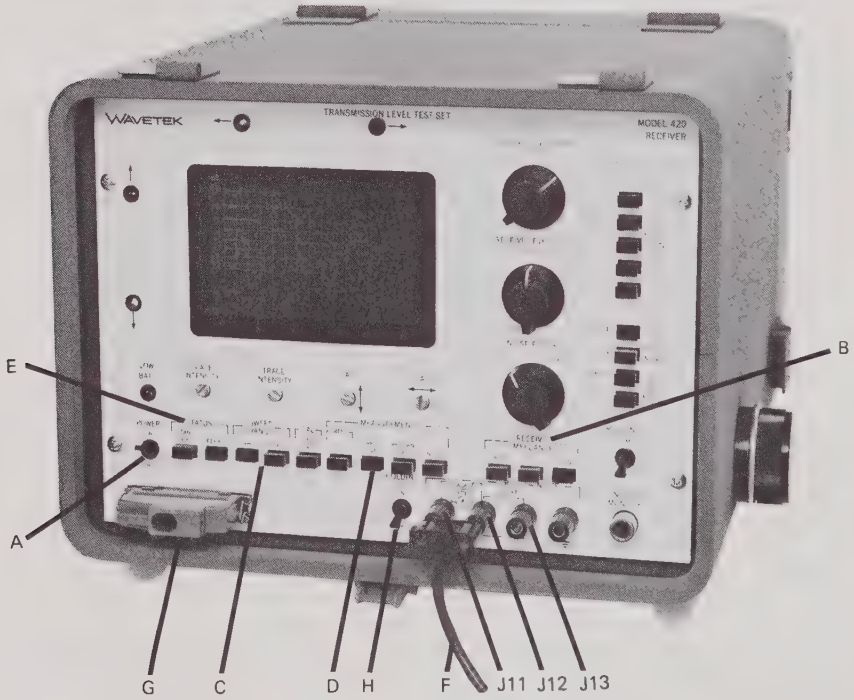
D. Circuit Under Test

4.12 Ensure that the circuit to be tested is idle and is available for test. Make it busy in accordance with standard practices.

4.13 Ensure that the circuit under test is properly terminated for the test to be made.

4.14 Consider whether the circuit under test contains echo-suppressors, in-band signalling equipment, or other apparatus which will respond to frequencies in the voice band. If so, take necessary steps to preclude the equipment from interfering with your test.

4.15 If the line connected to the transmitter or receiver is to be seized, ensure that the blocking capacitor at the Model 420 terminals is used.



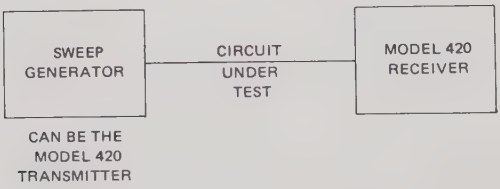


Figure 8. Received Level Setup

5. MEASUREMENTS

A. Received Level Measurement

5.01 Received level is the level in dBm of the signal received.

5.02 *Setup:* The letter beside each setup item keys the item to Fig. 8. See Note 1.

	Item	Receiver
A.	POWER	ON
B.	RECEIVE IMPEDANCE	See Note 2
C.	SWEEP RANGE	See Note 3
D.	MEASUREMENT	REC LEVEL
E.	STATUS	OPERATE (See Note 4)
F.	Circuit Under Test Connected to	J11, J12 (See Note 5)
G.	J1/J2 Cable or Jumper Plug Connected to	J1
H.	HOLDING COIL	See Note 5

Notes:

1. The Model 420 transmitter is not required at the receiving end to measure received level or transmission loss. If the Model 420 transmitter is used as the signal source, this measurement is "Transmission Loss". See Paragraph B, Transmission Loss Measurement, in this Section.

2. Press 600Ω or 900Ω to terminate the circuit under test in its characteristic impedance. Press BRIDG if the circuit under test is terminated elsewhere, and measurement is to be made without affecting the circuit under test.

3. Set the SWEEP RANGE to 5 kHz for a voice circuit, or to 15 kHz for a program circuit. The Model 420 receiver will follow the frequency of the received signal.

4. During battery operation (battery option), switch STATUS from OPERATE to STAND BY between measurements.

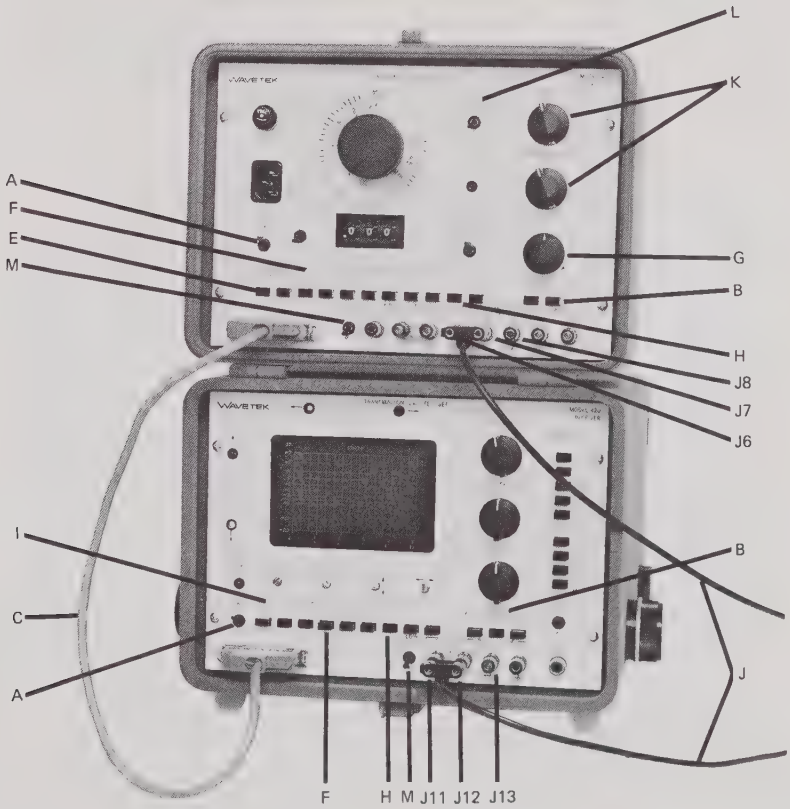
5. If battery of 24 or 48 volts is on the line to be measured or if the line is to be seized, connect the line under test to J12 and J13 of the receiver. An internal capacitor blocks dc without affecting the measurement. If a receiver-off-hook condition is required, flip HOLDING COIL switch to IN.

5.03 *Measurement:* Adjust the RECEIVE LEVEL attenuator so that the spot or trace is at or near zero dBm. The received level for a particular frequency is the algebraic sum of the setting of the two RECEIVE LEVEL attenuator switches and the position of the spot or trace at that frequency.

5.04 In the bridge impedance mode (BRIDG button pressed), the set is calibrated to measure power level in a circuit of 600Ω characteristic impedance; if the circuit under test is a 900Ω circuit, reduce the received level by 1.8 dB. This will correct for the difference in impedances.

5.05 The transmission loss, or circuit net loss, between the transmitter at the distant end of the circuit and Model 420 receiver is the algebraic difference between the transmitted level at the sending end, and the received level at the receiving end.

5.06 See Paragraph 6.D. for discussion on received level measurements.



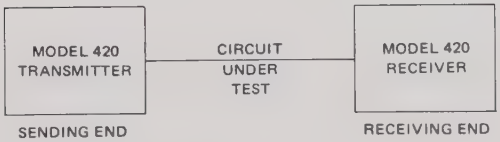


Figure 9. Transmission Loss Measurement Setup

B. Transmission Loss Measurement

5.07 Transmission loss is the difference in level between the transmitted signal and the received signal, expressed in dBm.

5.08 *Setup:* The letter beside each setup item keys the item to Fig. 9.

Item	Transmitter	Receiver
A. POWER	ON	ON
B. TRANSMIT and RECEIVE IMPEDANCE	See Note 1	See Note 1
C. J1/J2 Connecting Cable Connected to (See Note 2)	J2	J1
D. Jumper Plug	See Note 2	See Note 2
E. SWEEP MODE	AUTO	
F. SWEEP RANGE	See Note 3	See Note 3
G. SWEEP SPEED	As Required	
H. MEASUREMENT	TRAN LEVEL	REC LEVEL
I STATUS		OPERATE (See Note 4)
J. Circuit Under Test Connected to	J6, J7 (See Note 5)	J11, J12 (See Note 5)
K. TRANSMIT LEVEL	As Required	
L. Z COMPARE	OFF	
M. HOLDING COIL	See Note 5	See Note 5

Notes:

1. Press 600Ω or 900Ω button to terminate the circuit under test in its characteristic impedance. Press BRIDG button on the receiver if the receiving end of the circuit under test is terminated elsewhere, and the measurement is to be made without affecting the circuit.

2. The connecting cable can be connected, but is not required, between J1 and J2. The transmitter and receiver may be in different buildings at opposite ends of a long circuit. However, **J1 and J2 must have either the cable plug or jumper plug inserted to operate their power interlocks.**

3. Set the SWEEP RANGE on both the transmitter and receiver to 5 kHz when measuring a voice circuit, or to 15 kHz when measuring a program circuit or other circuit with a bandwidth exceeding about 4 kHz. The trace on the receiver follows the frequency of the received signal, and gives the level continuously over the band of frequencies selected.

4. During battery operation (battery option) switch the STATUS of the receiver to STAND BY between measurements. Switch transmitter POWER OFF when a substantial time will elapse between measurements.

5. If central office battery of 24 or 48 Vdc is on the circuit under test or the line is to be seized, connect the circuit under test to J7 and J8 on the transmitter, and J12 and J13 on the receiver. An internal capacitor in each set will block dc without affecting the measurements. If a receiver-off-hook condition is required, flip HOLDING COIL switch to IN.

5.09 *Measurement:* Adjust the RECEIVE LEVEL attenuator so that the spot or trace is at or near 0 dBm. The *received level* is the algebraic sum of the settings of the RECEIVE LEVEL dBm attenuator switches and the position of the spot or trace on the screen of the receiver.

5.10 The *transmission loss,* or *circuit net loss,* between the transmitter and the receiver is the algebraic difference between the transmitted level and the received level.

5.11 If the bridge impedance mode is used and the receiver is bridged across a 900Ω circuit that is properly terminated, reduce the received level reading by 1.8 dB. (Refer to Paragraph 3.11.)

5.12 See Paragraph 6.D. for discussion on transmission loss measurement.

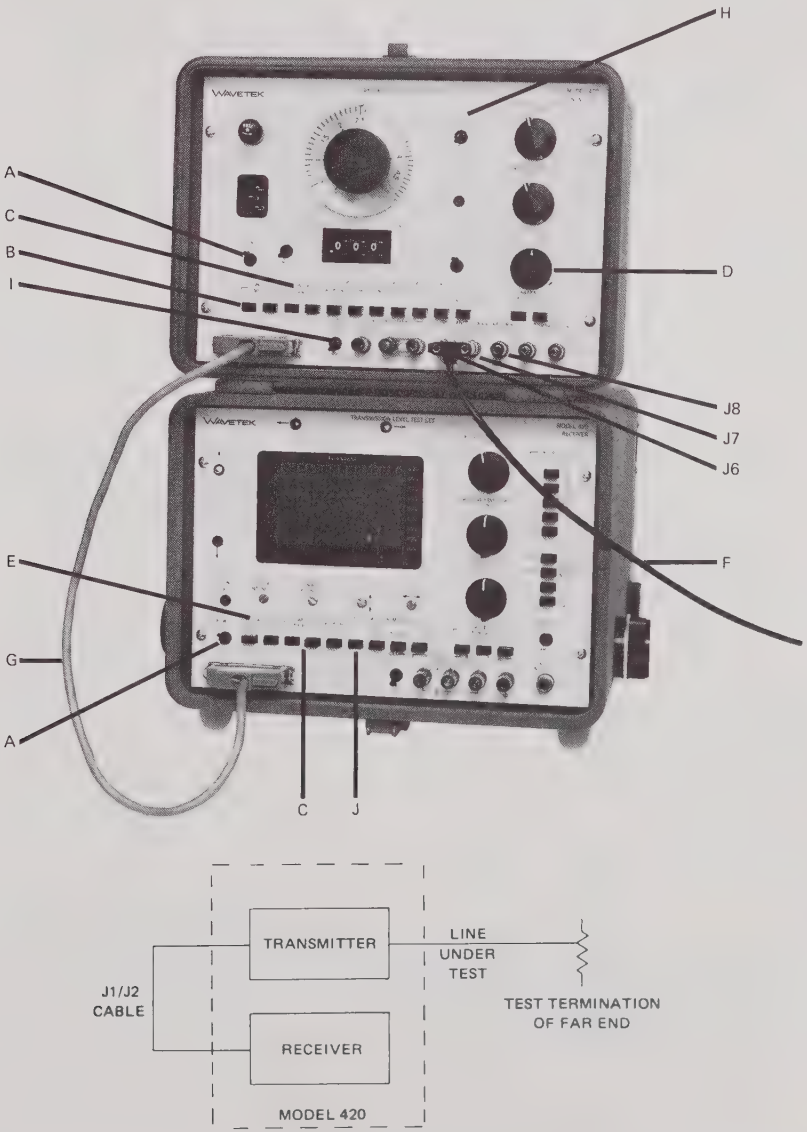


Figure 10. Impedance Measurement Setup

C. Impedance Measurement

5.13 Impedance is the ratio of voltage between the two wires in a circuit to the current in one of them. It is measured by:

(1) Sending a constant current from the transmitter into the line or circuit under test.

(2) Measuring the voltage across the line with the receiver.

5.14 The resulting trace of voltage versus frequency is calibrated directly in ohms, giving the magnitude of the measured impedance. The impedance phase angle is not indicated.

5.15 *Setup:* The letter beside each setup item keys the item to Fig. 10. The position of other controls will not affect impedance measurement.

Item	Transmitter	Receiver
A. POWER	ON	ON
B. SWEEP MODE	AUTO	–
C. SWEEP RANGE	See Note 1	See Note 1
D. SWEEP SPEED	As Required	–
E. STATUS	–	OPERATE (See Note 2)
F. Circuit Under Test Connected to	J6, J7 (See Note 3)	–
G. J1/J2 Cable Connected to	J2	J1
H. Z COMPARE	OFF	–
I. HOLDING COIL	See Note 3	–
J. MEASUREMENT	–	IMPED Z

Notes:

1. Set SWEEP RANGE on the transmitter for 5 kHz for most measurements on voice-grade facilities. Circuits and cable pairs for program and data may require conditioning beyond the usual cutoff frequency of voice-grade circuits; for this purpose, use the 15 kHz range.

2. During battery operation (battery option), switch the STATUS of the receiver to STAND BY between measurements. Switch transmitter POWER OFF when a substantial time will elapse between measurements.

3. If battery of 24 or 48 volts is on the line to be measured or if the line is to be seized, connect the line under test to J7 and J8. An internal capacitor blocks dc without affecting the measurement. If a receiver-off-hook condition is required, flip HOLDING COIL switch to IN.

5.16 *Measurement:* Adjust the position of the trace or spot on the receiver screen by means of the IMPEDANCE range switches on the transmitter. If the spot or trace is off the screen and the off-screen ↑ lamp lights, switch to a higher range; if the off-screen ↓ lamp lights, switch to a lower range. The measured impedance is the product of the deflection of the spot on the screen of the receiver and the IMPEDANCE range switch on the transmitter.

5.17 *Example:* Assume that the trace crosses the 1 kHz frequency mark at a level of 300Ω, and the Z X 5 IMPEDANCE range switch is depressed. The impedance of the circuit under test at 1 kHz is 300 X 5 = 1500 ohms.

5.18 See Paragraph 6.1. for discussion of impedance measurement.

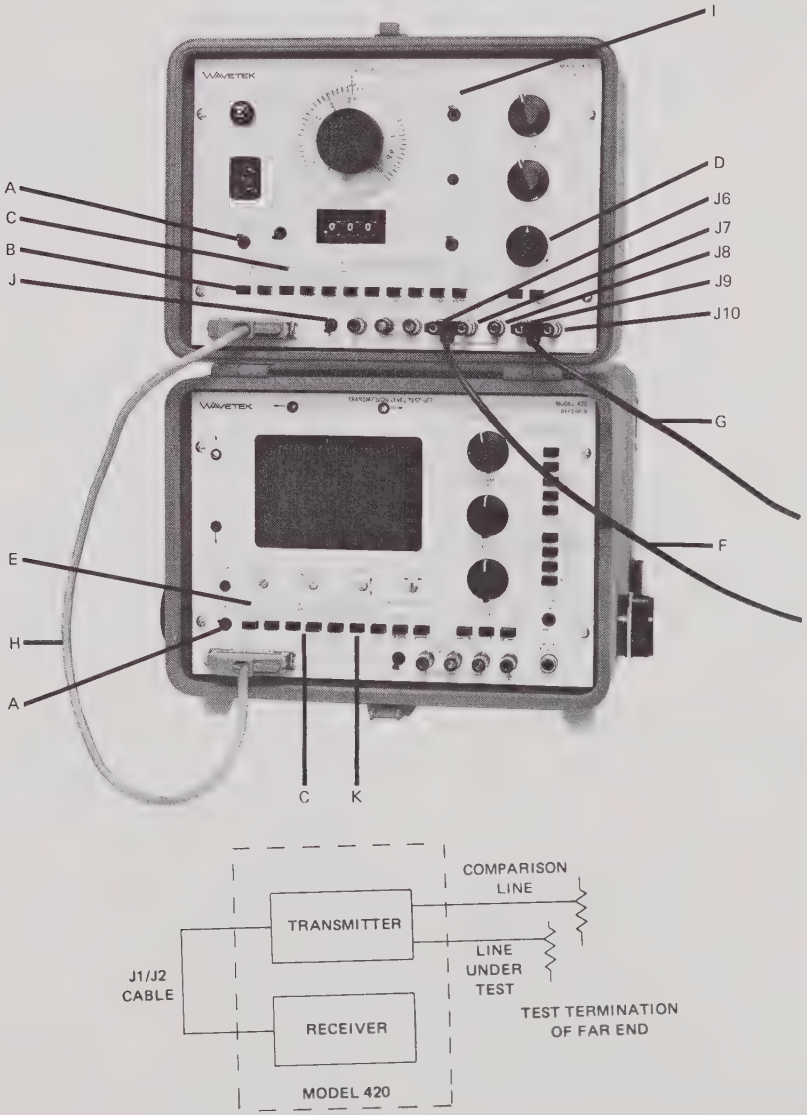


Figure 11. Impedance Comparison Setup

D. Impedance Comparison

5.19 Impedance comparison is the comparison of the total opposition that each of two circuits offer to the flow of alternating current. The comparison is made by:

(1) Sending a current from the transmitter into each line or circuit under test; transmitting a low-to-high swept frequency signal to one line or circuit and transmitting a high-to-low frequency signal to the other line or circuit.

(2) Measuring the voltage across the lines with the receiver. The characteristic curve of one line or circuit is solid, while the curve of the line receiving the AM signal is dotted.

5.20 The resulting traces of voltage versus frequency are calibrated directly in ohms, giving the magnitude of the measured impedance. The impedance phase angle is not indicated.

5.21 *Setup:* The letter beside each setup item keys the item to Fig. 11. The position of other controls will not affect impedance measurement.

Item	Transmitter	Receiver
A. POWER	ON	ON
B. SWEEP MODE	AUTO	–
C. SWEEP RANGE	See Note 1	See Note 1
D. SWEEP SPEED	As Required	–
E. STATUS	-	OPERATE (See Note 2)
F. Circuit Under Test Connected to	J6, J7 (See Note 3)	
G. Comparison Circuit Connected to	J9, J10	
H. J1 J2 Cable Connected to	J2	J1
I. Z COMPARE	ON (See Note 4)	
J. HOLDING COIL	See Note 3	–
K. MEASUREMENT	–	IMPED Z

Notes:

1. Set SWEEP RANGE on the transmitter for 5 kHz for most measurements on voice-grade facilities. Circuits and cable pairs for program and data may require conditioning beyond the usual cutoff frequency of voice-grade circuits; for this purpose, use the 15 kHz range.

2. During battery operation (battery option), switch the STATUS of the receiver to STAND BY between measurements. Switch transmitter POWER OFF when a substantial time will elapse between measurements.

3. If battery of 24 or 48 volts is on the line to be measured or if the line is to be seized, connect the line under test to J7 and J8. An internal capacitor blocks dc without affecting the measurement. If a receiver-off-hook condition is required, flip HOLDING COIL switch to IN.

4. The Z COMPARE switch can be set to IDENT (not shown in Fig. 11) to cause the characteristic curve of the line connected to terminals J6 and J7 to be dotted for identification purposes.

5.22 *Measurement:* Adjust the position of the trace or spot on the receiver screen by means of the IMPEDANCE range switches on the transmitter. If the spot or trace is off the screen and the off screen ↑ lamp lights, switch to a higher range; if the off screen ↓ lamp lights, switch to a lower range. Both traces should be observed. The measured impedance is the product of the deflection of the spot on the screen of the receiver and the IMPEDANCE range switch on the transmitter.

5.23 *Example:* Assume that the trace crosses the 1 kHz frequency mark at a level of 300Ω, and the Z X 5 IMPEDANCE range switch is depressed. The impedance of the circuit under test at 1 kHz is 300 X 5 = 1500 ohms.

5.24 See Paragraph 6.1 for discussion on impedance measurement.

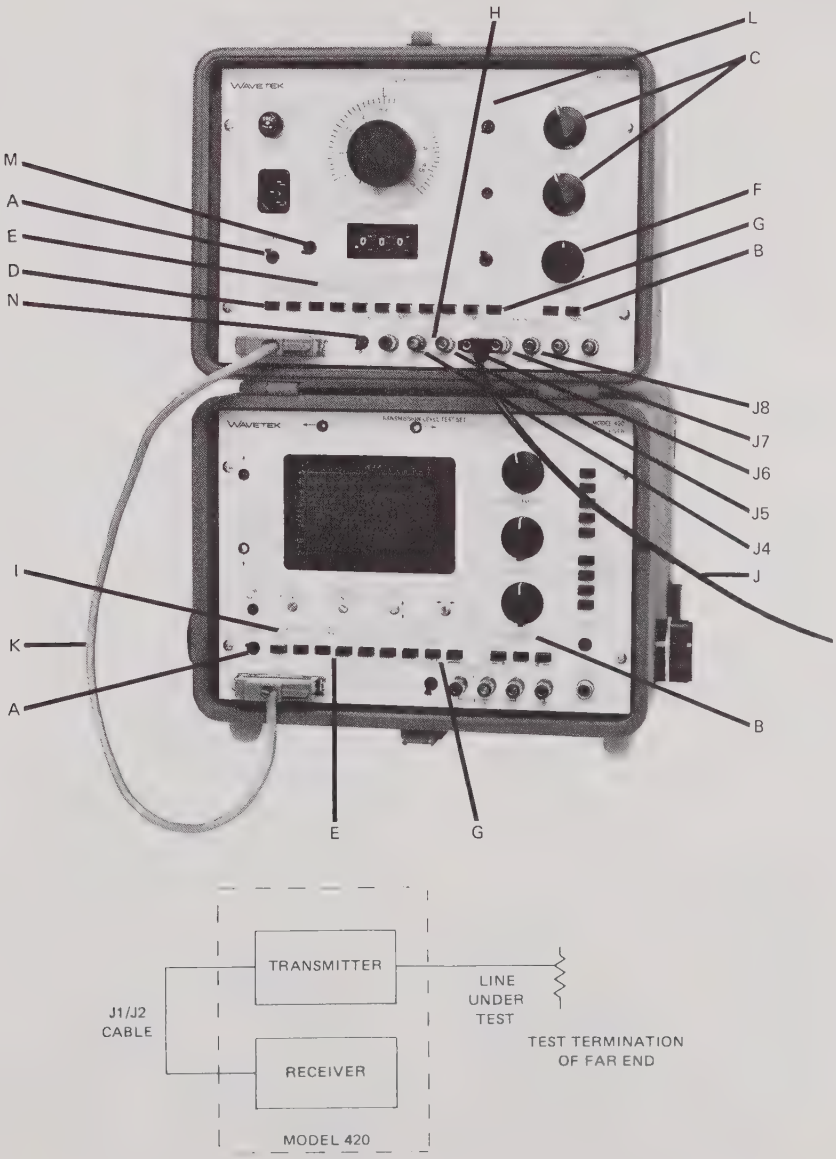


Figure 12. Two-Wire Return Loss Measurement Setup

E. Two-Wire Return Loss Measurement

5.25 Two wire return loss is the dB ratio of the power sent into a two-wire line to the power that returns from the line. It is the measure of the balance between the line and a standard comparison network.

5.26 Consider whether the circuit under test contains echo suppressors, in-band signalling equipment, or other apparatus which will respond to voice frequencies. If so, take steps necessary to preclude the equipment from interfering with your test.

5.27 *Setup:* The letter beside each setup item keys the item to Fig. 12.

Item	Transmitter	Receiver
A. POWER	ON	ON
B. TRANSMIT and RECEIVE IMPEDANCE	See Note 1	See Note 1
C. TRANSMIT LEVEL	0 dBm	–
D. SWEEP MODE	AUTO	–
E. SWEEP RANGE	5 kHz	5 kHz
F. SWEEP SPEED	As Required	–
G. MEASUREMENT	RETURN LOSS	RETURN LOSS
H. INTERNAL HYBRID COMPROMISE NETWORK	Short J4 to J5	–
I. STATUS	–	OPERATE (See Note 2)
J. Circuit Under Test Connected to	J6, J7 (See Note 3)	–
K. J1/J2 Cable Connected to	J2	J1
L. Z COMPARE	OFF	–
M. BUILDOUT CAPACITANCE	OUT	–
N. HOLDING COIL	See Note 3	–

Notes:

1. Set to 600Ω or 900Ω to terminate the line under test in its characteristic impedance at the measuring end. Also, terminate the line under test at the far end.

2. During battery operation (battery option), switch STATUS from OPERATE to STAND BY between measurements. Switch transmitter POWER OFF when a substantial time will elapse between measurements.

3. If battery of 24 or 48 volts is on the line to be measured or if the line is to be seized, connect the line under test to J7 and J8. An internal capacitor blocks dc without affecting the measurement. If a receiver-off-hook condition is required, flip HOLDING COIL switch to IN.

5.28 *Measurement:* Adjust the RECEIVE LEVEL attenuator so that the spot or trace is at or near 0 dBm. The *received level* is the algebraic sum of the settings of the RECEIVE LEVEL attenuator switches and the position of the spot or trace on the screen of the receiver.

5.29 The *measured return loss* is the algebraic difference between the transmitted level of the transmitter, and the received level of the receiver. The Model 420 automatically accounts for the trans-hybrid loss, and reads return loss directly without correction.

5.30 See Paragraph 6.J for discussion of two-wire return loss.

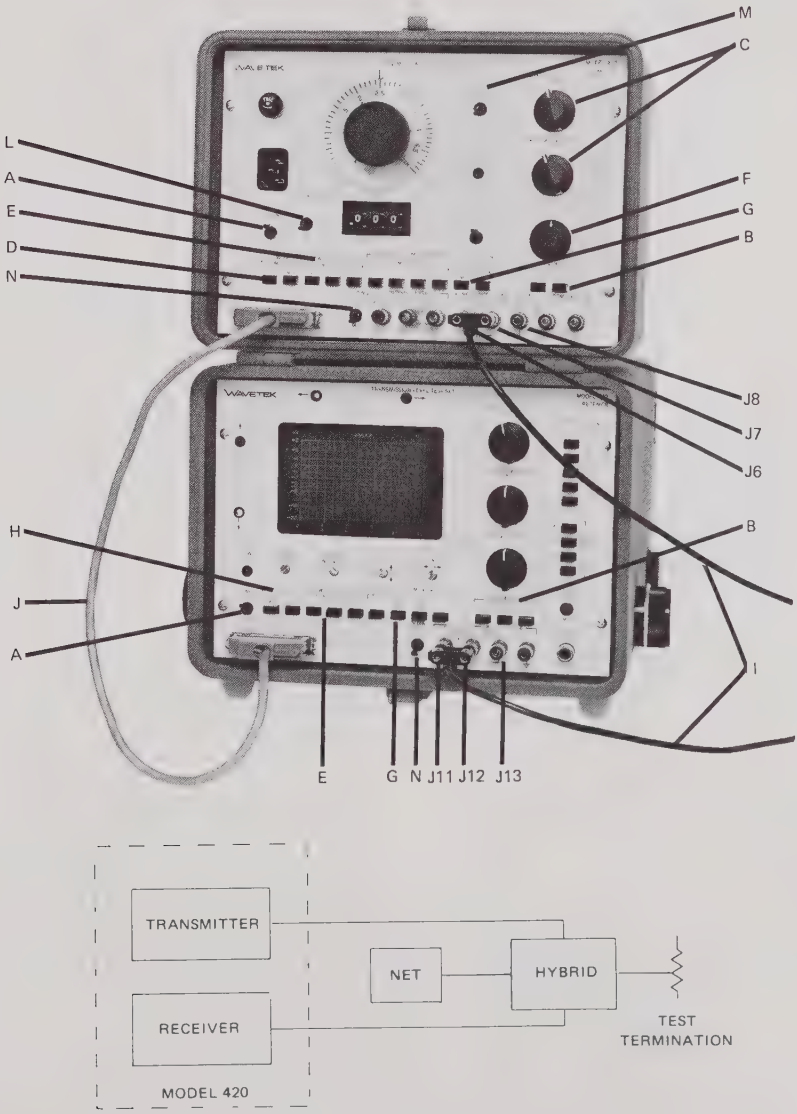


Figure 13. Four-Wire Return Loss Measurement Setup

F. Four-Wire Return Loss Measurement

5.31 Four-wire return loss is a measurement of the portion of single-frequency power transmitted thru a hybrid into a two-wire line that is returned thru the hybrid to the other side.

5.32 *Setup:* The letter beside each setup item keys the item to Fig. 13.

Item	Transmitter	Receiver
A. POWER	ON	ON
B. TRANSMIT and RECEIVE IMPEDANCE	See Note 1	See Note 1
C. TRANSMIT LEVEL	See Note 2	–
D. SWEEP MODE	AUTO	–
E. SWEEP RANGE	5 kHz (See Note 3)	5 kHz (See Note 3)
F. SWEEP SPEED	As Required	–
G. MEASUREMENT	TRAN LEVEL	REC LEVEL
H. STATUS	–	OPERATE (See Note 4)
I. Circuit Under Test Connected to	J6, J7 (See Note 5)	J11, J12 (See Note 5)
J. J1/J2 Cable Connected to	J2 (See Note 6)	J1 (See Note 6)
K. Jumper Plug Connected to	See Note 6	See Note 6
L. BUILDOUT CAPACITANCE	OUT	
M. Z COMPARE	OFF	
N. HOLDING COIL	See Note 5	See Note 5

Notes:

1. Set to 600Ω or 900Ω to terminate the line under test in its characteristic impedance. Terminate the two-wire side of the circuit under test in a standard termination, or in a test drop in off-hook condition.

2. The four-wire return loss test is usually made at the four-wire side of the four-wire terminating set (4 TS). The transmission levels at this point depend upon the overall circuit net loss, and the TLP. See Paragraph 6.D.

3. The 5 kHz range will enable you to observe frequencies well beyond cut-off point of voice-grade circuits. If you are testing program circuits, or especially conditioned data circuits, you may need to use the 15 kHz range to cover the entire bandwidth.

4. During battery operation (battery option), switch STATUS from OPERATE to STAND BY between measurements. Switch transmitter POWER OFF when a substantial time will elapse between measurements.

5. If central office battery of 24 or 48 Vdc is on the circuit under test or the line is to be seized, connect the circuit under test to J7 and J8 on the transmitter, and J12 and J13 on the receiver. An internal capacitor in each set will block dc without affecting the measurements. If a receiver-off-hook condition is required, flip HOLDING COIL switch to IN.

6. The J1/J2 cable connection can be used between the transmitter and receiver, but is not required. The transmitter and receiver may be in different buildings at opposite ends of a long circuit. However, J1 and J2 must have either the cable plug or jumper plug inserted to operate their power interlocks.

5.33 *Measurement:* Adjust the RECEIVE LEVEL attenuator so that the spot or trace is at or near 0 dBm. The *received level* is the algebraic sum of the settings of the RECEIVE LEVEL attenuator switches and the position of the spot or trace on the screen of the receiver. Observe the *received level* with the circuit under test properly terminated. Then place a short circuit across the two wire line terminals of the hybrid and observe the *received level* without changing the transmit level. Subtract the first reading (with circuit terminated) from the second (with hybrid shorted). The difference is the *return loss*.

5.34 See Paragraph 6.36 for discussion of four-wire return loss.

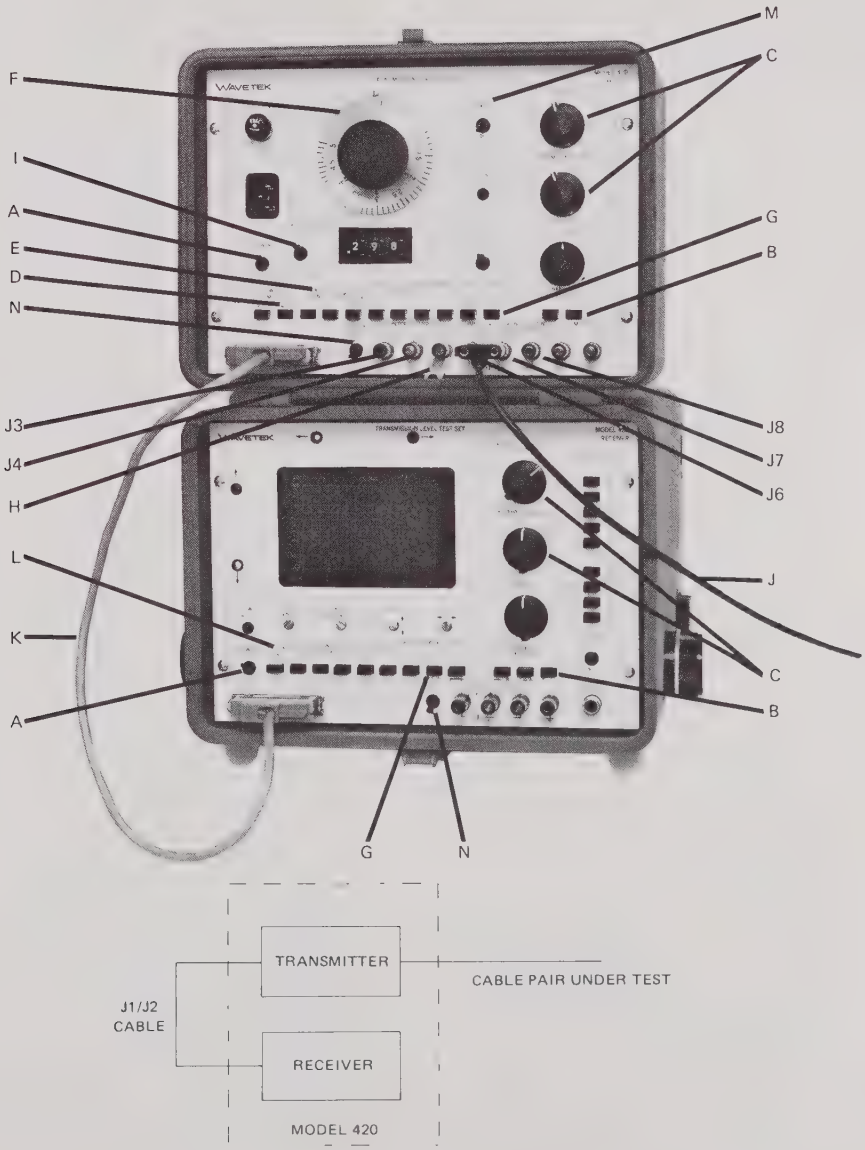


Figure 14. Cable Length Measurement Setup

G. Cable Length Measurement

5.35 The length of a pair of wires in a cable is proportional to their capacitance. The capacitance is found by matching the capacitance of the precision network leg of the internal hybrid with the capacitance of the cable pair. If the cable pair capacitance per mile is known, the number of miles of cable is easily calculated.

5.36 *Setup:* The letter beside each setup item keys the item to Fig. 14.

Item	Transmitter	Receiver
A. POWER	ON	ON
B. TRANSMIT and RECEIVE IMPEDANCE	900Ω	900Ω
C. TRANSMIT and RECEIVE LEVEL	0 dBm	−20 dBm
D. SWEEP MODE	MAN	–
E. SWEEP RANGE	5 kHz	5 kHz
F. FREQUENCY	50 Hz (Full Clockwise)	–
G. MEASUREMENT	RETURN LOSS	RETURN LOSS
H. INTERNAL HYBRID COMPROMISE NETWORK	Short Removed	–
I. BUILDOUT CAPACITANCE	IN (See Note 1)	–
J. Pair Under Test Connected to	J6, J7 (See Note 2)	–
K. J1/J2 Cable Connect to	J2	J1
L. STATUS	–	OPERATE (See Note 3)
M. Z COMPARE	OFF	–
N. HOLDING COIL	OUT	OUT

Notes:

1. If the instrument does not have the Buildout Capacitance Option, place a decade capacitor between J3 and J4.

2. Clear the cable pair and leave open at the distant end.

3. During battery operation (battery option), switch STATUS from OPERATE to STAND BY between measurements. Switch transmitter POWER OFF when a substantial time will elapse between measurements.

5.37 *Measurement:* Adjust the BUILDOUT CAPACITANCE for maximum return loss, typically −40 dB. The BUILDOUT CAPACITANCE will equal the capacitance of the cable. Use Fig. 15 to determine cable mileage.

5.38 *Example:* The measured capacitance of the cable pair was found to be 0.16 μF. Records show the capacitance for this type of cable to be 0.083 μF/mile. As shown in Fig. 15, the intersection of the 0.16 μF line and the 0.083 μF/mile line determines the 3800 ft length.

5.39 See Paragraph 6.1. for discussion on cable length measurement.

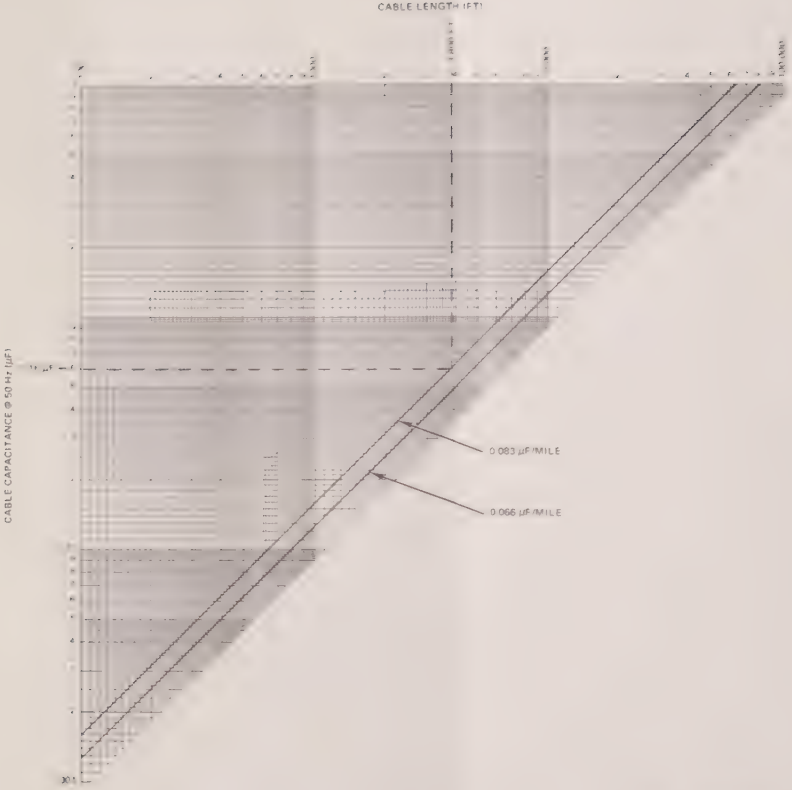
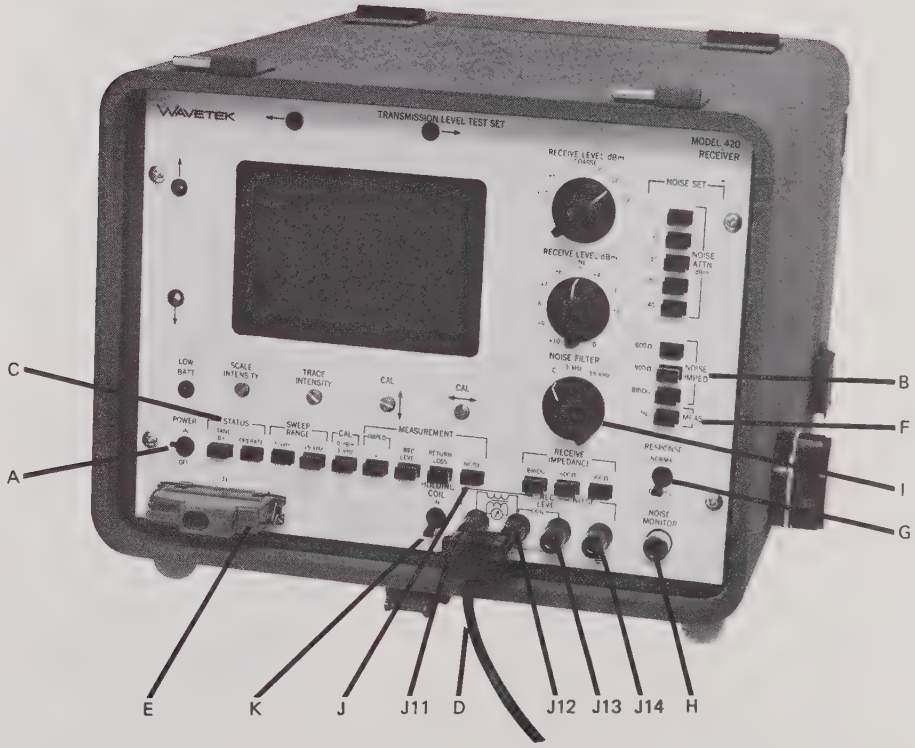


Figure 15. Cable Length Chart



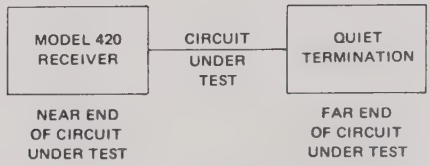


Figure 16. Noise Measurement Setup

H. NOISE MEASUREMENT (NOISE OPTION)

5.40 Noise level is the ratio of the average power of undesired disturbance in the useful frequency range to a standard reference power level.

5.41 When measuring noise, the receiver does not follow frequency of received signals. It averages the power over the voice band in accordance with the weighting of the noise filter that is used (C-message, 3 kHz flat, or 15 kHz flat), and indicates this average power by its vertical deflection near the horizontal center of the screen.

5.42 *Setup:* The letter beside each setup item keys the item to Fig. 16. See Note 1.

	Item	Receiver
A.	POWER	ON
B.	NOISE IMPED	See Note 2
C.	STATUS	OPERATE (See Note 3)
D.	Circuit Under Test Connected to	J11, J12 (See Note 4)
E.	J1/J2 Cable or Jumper Plug Connected to	J1
F.	MEAS Ng	Extended
G.	RESPONSE	DAMPED
H.	NOISE MONITOR	See Note 5
I.	NOISE FILTER	C
J.	MEASUREMENT	NOISE
K.	HOLDING COIL	See Note 4

Notes

1. The Model 420 transmitter is not required for noise measurements

2. Press the 600Ω or the 900Ω button of the NOISE IMPEDANCE switch to terminate the circuit under test in its characteristic impedance at the measuring end. If the circuit is terminated elsewhere, and the measurement is to be made without disturbing the circuit under test, push the BRIDG button. Terminate the far end of the circuit in the proper impedance for the circuit. This may be a quiet termination dialed up over the circuit, or a resistor connected across the terminals at the distant end. At a four-wire point in the circuit, terminate both sides.

3. When operating the receiver on self-contained batteries (battery option), switch STATUS from OPERATE to STAND BY between measurements.

4. If battery of 24 or 48 volts is on the line to be measured or if the line is to be seized, connect the line under test to J12 and J13 of the receiver. An internal capacitor blocks dc without affecting the measurement. If a receiver-off-hook condition is required, flip HOLDING COIL switch to IN.

5. Plug headphones into the NOISE MONITOR jack if monitoring is desired.

5.43 *Measurement:* Depress the combination of NOISE ATTN buttons that will cause the spot or trace on the screen to be near 0 dB. (Press to raise, press-to depress.) The measured noise level is the algebraic sum of the attenuator setting (count the values corresponding to buttons which are depressed) and the deflection of the spot on the screen.

5.44 *Noise-to-Ground:* The above setup will measure noise metallic. To measure noise-to-ground, press the MEAS Ng button. This will arrange the set to measure longitudinal noise. For this measurement, J14 must be connected to the telephone ground. (Avoid frame ground, signal ground and power ground.) Add a 40 dB correction to the reading.

5.45 See Paragraph 6.K. for discussion of noise measurements.

6. GENERAL CONSIDERATIONS

A. Battery

6.01 Battery on the circuit under test will saturate the transformer in the Model 420 if the circuit is connected directly. If the circuit has battery on it (24 or 48 volt central office battery, or telegraph battery, for example), connect it thru the blocking capacitor terminal. Generally, it is preferable to connect the side with battery, the ring side, to the jack with the capacitor: J8 on the transmitter or J13 on the receiver.

B. Receiver Off Hook

6.02 If a receiver-off-hook condition is required, flip the HOLDING COIL switch to IN.

C. Ground Connections

6.03 Jacks J9 on the transmitter (without the Z comparison option) and J14 on the receiver are connected to chassis ground inside the cases. This is separate from the circuit ground, or the low potential side of the circuit (J7 on transmitter and J12 on receiver). When used to measure noise-to-ground, this jack should be connected to the ground connection of the apparatus, or circuit under test as close to the apparatus or circuit as is possible. On a cable pair at the distributing frame, this will be the cable sheath. In a central office, this will generally be the ground for talking battery, or the terminal on the apparatus under test to which talking-battery ground is connected. Avoid connecting the ground jack of the test set to signal ground, frame ground, or ac power ground.

6.04 A difference in potential between ground jack, J9 or J14, and the ground connection of the circuit under test could affect the measurement. This difference in potential is minimized by proper connection of the ground jack thru a conductor of very low impedance.

D. Transmission Level

6.05 The recommended transmitting level for test tone is 13 dB below one milliwatt at the 0 Test Level Point (TLP), which is −13 dBm0 on voice circuits. The 0 TLP is a point of reference in the circuit under test to which transmission losses and levels are referred. It may be theoretical only, and not physically accessible.

6.06 Historically, when toll circuits were commonly designed to 9 dB loss, when operators did all of the toll switching, and when signalling was ring-down, the common practice was to apply test tone at 1 mW and 1 kHz to the circuit at the toll switchboard at one end, and to measure the received power at the toll switchboard at the other end. The manual toll switchboard, the 9 dB trunk, and ring-down operation have virtually disappeared. The 0 TLP is a vestige of that era. In a machine-switching toll office, the 0 TLP is a figment of the engineers' imagination; the practical access to a trunk is at the outgoing switch, where the design value is −2 dBm0, so this access point becomes a −2 TLP. The designation "−2 dBm0" in Fig. 17 means the same thing: −2 dB referred to 1 mW at the 0 TLP.

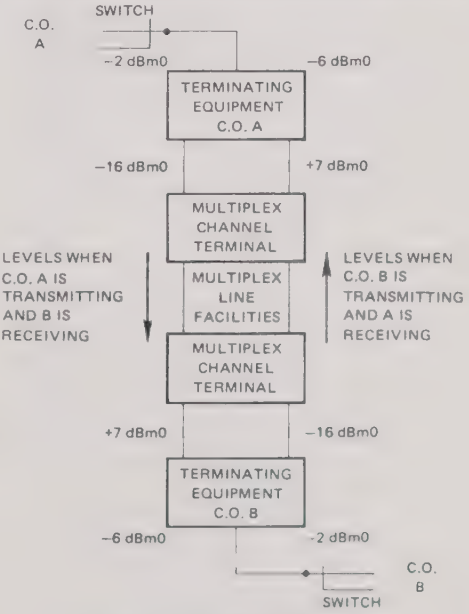


Figure 17. Transmission Levels of a Typical Two-Wire Trunk with 4 dB Loss

6.07 The recommended level of 13 dB below 1 mW at the 0 TLP is currently recommended because:

(1) It approximates the power of the analog signal of an average talker on a voice circuit.

(2) It is the recommended level for tones used in the transmission of digital data on voice circuits.

6.08 TLP, Transmission Level Point, is sometimes called Test Level Point. The number preceding it (0, −2, or +7, for example) is the algebraic sum of the gains and losses between the TLP under consideration, and the 0 TLP, or reference point. Fig. 17 illustrates some typical transmission levels in a two-wire trunk that is designed for an overall circuit net loss of 4 dB.

6.09 For example, if 1 mW were to be sent thru a 2 dB pad into the switch of the trunk of Fig. 17 (the −2 TLP) then at the output of the terminating equipment, you should measure −16 dBm (1 mW down 16 dB). If the test tone were sent at the recommended level, that is, −13 dBm0, then you would read −29 dBm at the −16 TLP.

6.10 Similarly, if you are required to send −13 dBm0 into the multiplex channel terminal, which usually is a −16 TLP, the proper transmit level of the Model 420 transmitter would be −29 dBm; and the attendant at the output of the multiplex channel (+7 TLP) should read −6 dBm. Fig. 18 illustrates similar typical transmission levels on a foreign exchange subscriber line.

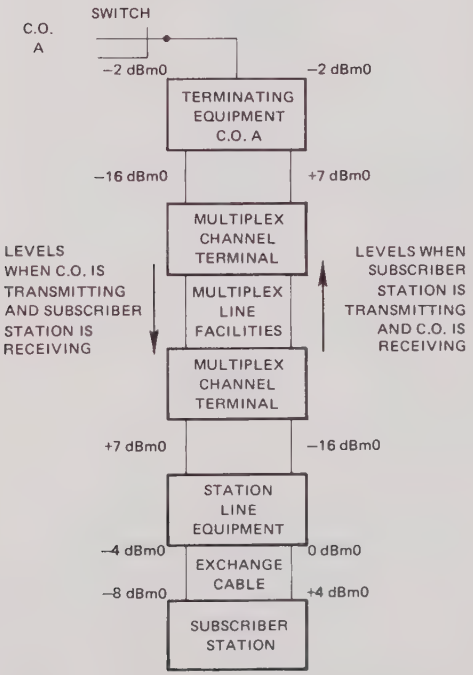


Figure 18. Transmission Levels of a Typical Foreign Exchange Station Line with 6 dB Loss Overall, and 4 dB Loss in Subscriber Loop

E. Circuit Termination

6.11 The impedance of the circuit under test is quite sensitive to the termination of the far end. If the far end is open (infinite impedance), the constant-current generator produces a high voltage across the terminals, which is indicated as a high impedance. If the far end is short-circuited (zero impedance), the constant-current generator produces a low voltage across the terminals which is indicated as low impedance. This effect is especially noticeable at low end of the frequency scale.

6.12 As the terminating impedance is changed from zero to infinite, the valleys in the trace tend to fill up and the peaks tend to flatten out. There is a value of terminating impedance at which the trace is virtually a straight line.

6.13 Both ends of a circuit under test must be properly terminated in order to obtain accurate measurements. Generally speaking, private lines, leased lines, toll circuits, trunks in toll offices, and multiplex channels are designed to 600Ω characteristic impedance. These circuits are properly terminated in a standard impedance, or compromise network, consisting of 600Ω resistance in series with a capacitance of 2.14 or 2.16 μF. Subscriber lines, PBX trunks, exchange inter-office trunks, and tandem trunks are usually designed to 900Ω impedance. These circuits are properly terminated in a standard impedance or compromise network of 900Ω resistance in series with 2.15 μF* capacitance. For some measurements, 1 kHz circuit-net-loss measurements, for example, a simple resistor is adequate, and the capacitance may be omitted. Impedance measurements, balance measurements, and return loss measurements are more critical, and frequently require special terminations and balancing networks tailored to the office in which the circuit terminates.

6.14 The Model 420 is designed to provide the proper termination, 600Ω, or 900Ω, for the circuit to which it is connected for test. Both the transmitter and the receiver are calibrated to transmit or indicate the correct power level in the impedance selected by the TRANSMIT IMPEDANCE and the RECEIVE IMPEDANCE switches, respectively.

6.15 The BRIDG connection of the receiver gives it an input impedance greater than 25,000Ω. This connection is used to measure the level on a circuit which is terminated elsewhere in its characteristic impedance, and to do so without absorbing any appreciable amount of power from the circuit under test. In the bridge mode, the receiver is calibrated to indicate the power level in a 600Ω circuit that is properly terminated. If the impedance of the circuit under test is 900Ω, the RECEIVE LEVEL measured

* The capacitor in the Model 420 is 2.15 μF ±1%, a compromise between the two standards of 2.14 μF and 2.16 μF. This compromise produces an error of less than ±0.1%.

in the bridge mode must be reduced by 1.8 dB to correct for the difference in impedances. For example, if the uncorrected bridge measurement of RECEIVE LEVEL on a 900Ω circuit is −4.8 dBm, the correction of −1.8 dB is added algebraically to give a corrected reading of −6.6 dBm.

6.16 Similar considerations apply to bridging impedance mode measurements of noise or 900Ω circuits. However, rapid, short-time fluctuations and slow variations in noise power are generally greater than the value of the correction. For this reason, the 1.8 dB correction will not add much to the precision of most noise measurements, and it can usually be neglected.

F. Echo Suppressors

6.17 The circuit under test may contain equipment that responds to frequencies in the voice band in such a way as to interfere with your tests. Fig. 19 illustrates a typical arrangement of terminal equipment. The Model 420, in the auto sweep mode, continuously sweeps the voice band, sending consecutively all frequencies between 50 and 5000 Hz (or 150 and 15,000 Hz in the 15 kHz range). This will affect echo suppressors, single frequency signalling equipment, and perhaps other equipment.

6.18 If the circuit under test is a toll message circuit longer than about 1500 miles, or a private line longer than about 2000 miles, it will probably contain an echo suppressor. An echo suppressor is a device on a telephone circuit that detects voice frequencies in one direction of transmission and increases the loss in the opposite direction of transmission. The device operates quickly enough at the start of a burst of speech to avoid clipping the first syllable of a word, and it remains operated long enough to attenuate the echo of the last syllable in the burst.

6.19 To permit full duplex operation for transmission of data, echo suppressors are arranged to disable themselves on receipt of a spurt of single-frequency tone of 2150 ±150 Hz which lasts more than 750 ms. On receipt of the signal, the echo suppressor will disable itself, and will remain disabled so long as it detects energy in the band between 800 and 2800 Hz. When energy between 800 and 2800 Hz is interrupted for more than 50 ms, the echo suppressor restores itself to normal operation. The required level for both the disabling tone and the energy at frequencies in the holding band is between −16 dBm0 and 0 dBm0.

6.20 The frequency of the Model 420, in auto sweep mode and 5 kHz range, is outside the holding band of 800 to 2800 Hz longer than 50 ms at each end of each sweep. Therefore, in the auto sweep mode, at the fastest sweep rate, the Model 420 will not keep the echo suppressor disabled.

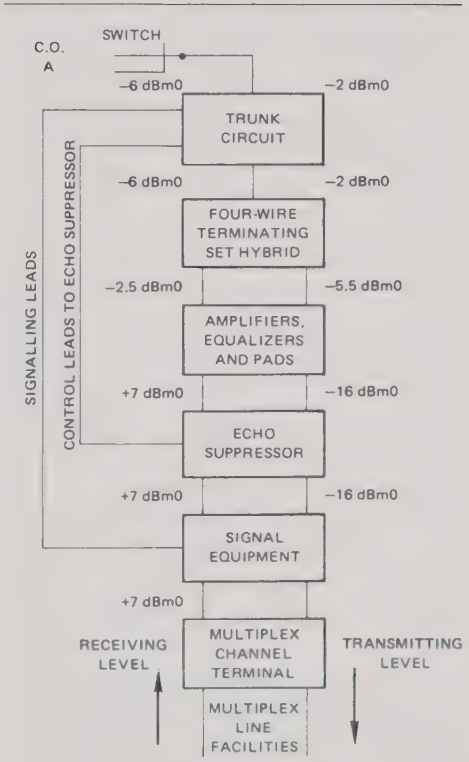


Figure 19. Transmission Levels of a Typical Arrangement of Terminal Equipment for a Two-Wire Trunk with 4 dB Loss

6.21 You may prevent the echo suppressor from interfering with the tests in either of two ways:

(1) Manually block the echo suppressor in accordance with standard practices. This will disable it mechanically.

(2) Switch the Model 420 transmitter to manual sweep mode, and control the frequency manually to send the disabling tone and to keep the test signal within the holding band.

G. Alternating Current Signalling

6.22 Alternating current signalling on telephone circuits is usually in-band at 2600 Hz. Circuits arranged for out-of-band signalling (very rare in the USA) separate the voice band, 300 to 3400 Hz, from the signalling frequency, 3700 Hz, in such a manner that the out-of-band signalling features will not interfere with tests and measurements made at the usual access points for voice-frequency testing. In-band signalling equipment, also called "single-frequency signalling," responds to single-frequency tone in the voice band; hence, it may interfere with transmission of the sweep-frequency signal of the Model 420 transmitter.

6.23 The frequency of signal tone in the in-band, or single-frequency signalling system is 2600 ±50 Hz in both directions on four-wire circuits, and one way on two-wire circuits; signalling in the other direction on two-wire circuits is at 2400 ±50 Hz. These frequencies are detected and interpreted as signal frequencies as long as there is no detectable energy present at other frequencies in the voice band. The tones are present during idle condition, and absent during the talking condition of the circuit. Sensitivity of the signalling equipment is −29 dBm0 on four-wire circuits, and −32 dBm0 on two-wire circuits. To prevent false operation, a signalling unit has a "guard time delay" of 35 ms during which it may receive power at signalling frequency without functioning.

6.24 Model 420 transmitter, in auto sweep mode at maximum sweep speed, crosses the voice band in about one-half second, which is a rate of about 50 Hz per ms. At this rate, the test power is not at signal frequency long enough to operate a properly adjusted single-frequency signalling unit. If the test tone does inadvertently operate the signalling unit, the unit will operate as follows:

(1) Disconnect a dialled-up connection.

(2) Transmit ringing current to the distant end of the circuit.

(3) Perform some other supervisory function.

6.25 If the tests are extensive, it is recommended that the circuit be turned down, and the signalling equipment blocked in accordance with standard practices to avoid interfering with sweep-frequency tests.

H. Transmission Loss and Loss-Frequency Measurements

6.26 Requirements for received level or circuit net loss are given as part of the design data for acceptance tests and usually are in the circuit layout records for maintenance purposes. Figs. 17 and 18 illustrate a typical trunk, and a typical long station line. The levels shown in the diagrams are typical of standard practice.

6.27 Adjust the RECEIVE LEVEL attenuator switches so that the trace at 1 kHz is 0 dBm on the screen. Then, deviations from 1 kHz for any frequency may be read directly from the screen and compared with the requirements for the circuit under test without regard to circuit loss, reference level, or TLP.

6.28 On trunks for data services, typical requirements for deviation from the level at 1 kHz are the following:

(1) Between 350 Hz and 2 kHz, the level should be not more than 1 dB above, nor 3.5 dB below the level at 1 kHz.

(2) Between 2 and 2.5 kHz, the level should be not more than 2.0 dB above, nor 5.0 dB below that at 1 kHz.

I. Internal Hybrid (Impedance Bridge) Use

6.29 In addition to the measurements detailed in Section 5.C., the internal hybrid circuit may be used in the following manner.

6.30 In the RETURN LOSS mode, the Model 420 is a very sensitive measuring bridge. To use it as such, disconnect the shorting link between J4 and J5 and connect a calibrated impedance to J3 and J4. This may be a decade resistor, decade capacitor, variable inductor, or a combination of these. Adjust the calibrated impedance to obtain null. The null is indicated by the lowest received level indicated by the receiver. Slight changes in either direction from balance will cause the trace to indicate an increase in level. The null is most easily obtained with the SWEEP MODE set to MAN and a suitable single frequency selected for the adjustment.

6.31 If the length and capacitance per unit length of the cable are known, the measurement of capacitance with Model 420 will give information from which you may detect bridged taps, and deviation from specified capacitance due either to water in the cable, or variation in insulation and spacing during manufacture.

6.32 To match an artificial line to a cable pair under test, use the impedance bridge in the Model 420 as follows:

(1) Set up the Model 420 for impedance measurement, connect the cable pair and record the impedance versus frequency trace using the Polaroid camera accessory to the Model 420.

(2) Set up the Model 420 for two-wire return loss (Section 5.D.).

(3) Disconnect the shorting link between J4 and J5, and connect the cable pair under test to PRECISION NETWORK terminals J3 and J4; connect the artificial line to measuring terminals J6 and J7. (This is to facilitate checking the impedance trace of the artificial line as you approach a balance with the real line.)

(4) Adjust the artificial line to obtain a null in the RETURN LOSS mode.

6.33 In theory a perfect balance would produce a null at each individual frequency. In order to check your progress against the recorded impedance curve, press the IMPEDANCE Z switches on both the transmitter and receiver. The trace will be the impedance trace of the artificial line. Without disconnecting either the artificial line or the real line, and without changing your TRANSMIT and RECEIVE LEVEL switch adjustments, you can compare the previously recorded picture of the impedance of the real line with the trace of the artificial line while you approach a balance with the artificial line.

J. Return Loss Measurements

6.34 Return loss is the dB ratio of the power sent into a two-wire line at a given frequency to the power that "returns" from the line. It is an indirect measure of the difference in impedance between the line and its balancing network. On a working telephone circuit, the return loss gives a measure of how much of a talker's speech power will return to him as echo. The smaller the amount of returned power, the greater is the return loss, and the better is the circuit.

6.35 Two-wire return loss is measured by connecting the line under test to the internal hybrid. The sweep generator in the transmitter applies a signal to the transmitting terminals of the internal hybrid; the internal compromise network balances the line under test; the receiver detects and displays a signal in the receiving connection of the internal hybrid as a measure of the difference between the impedances in the line under test and in the compromise network. Fig. 3 illustrates schematically the internal connections.

6.36 Four-wire return loss is a measurement of the proportion of single-frequency power transmitted thru a hybrid into a two-wire line that is returned thru the hybrid to the other side. Fig. 20 illustrates a typical setup at a PBX, and Fig. 21 at a toll office. The test is made on the four-wire side of the hybrid that is normally connected in the circuit, and is distinguished from the two-wire return loss, which is made at a point where the circuit is a two-wire circuit and uses the internal hybrid in the Model 420.

6.37 For practical purposes, return loss is separated into *echo return loss* and *singing return loss.* Echo return loss is usually measured by sending white noise thru a filter which passes only the band of frequencies between 500 and 2500 Hz. The portion of this power that is returned is measured as a weighted average over the frequency band, using a noise measuring set.

6.38 CCITT* gives a method of measuring echo return loss, using the trapezoidal rule for numerical integration, that will give a comparable weighted average. In this method, the return losses at the single frequencies 500, 1000, 1500, 2000, and 2500 Hz are measured individually. The dB readings are converted to power ratios (the power

*The International Telegraph and Telephone Consultative Committee

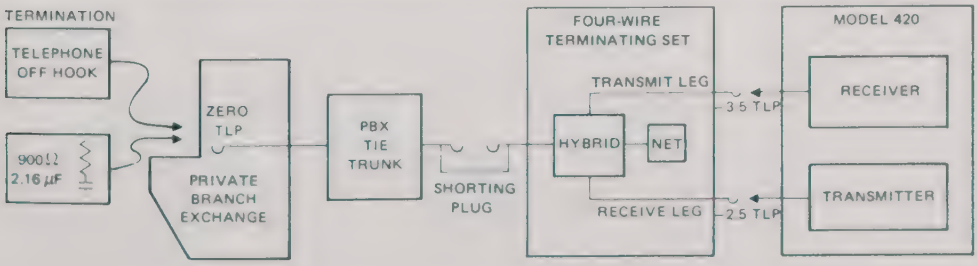


Figure 20. Typical Setup for Four-Wire Return Loss Measurement on a 6 dB Tie Trunk

ratio = $\log^{-1}$ [dB/10]). Use Fig. 22 for rapid conversion of values. Fifty percent of the ratio for 500 Hz, and 50% of the ratio for 2500 Hz are added to the sum of the ratios at the other three frequencies; the total is divided by four, giving a weighted average ratio; this ratio is converted back to dB where dB = 10 X Log_{10} Power Ratio. Use Fig. 22. The dB values of the four frequencies for this method can be read on the screen of the Model 420 receiver.

6.39 For an example, in a measurement, the five points seen on the trace are as in the first two columns of the table below. Then, from Fig. 22, the power ratios are as given in the third column, and the weighted ratios in the fourth column.

Measured		Power Ratio	
Frequency	Loss	Measured (Look up in Fig. 22)	Weighted
500	30 dB	0.0010 X .5	0.0005
1000	25 dB	0.0032	0.0032
1500	28 dB	0.0016	0.0016
2000	35 dB	0.0003	0.0003
2500	23 dB	0.0050 X .5	0.0025
		Total	0.0081
		÷ 4 =	0.0020

Look up power ratio 0.0020 in Fig. 22 for a Weighted Average Return Loss of 27 dB.

6.40 Singing return loss is a measure of stability of the voice circuit that results from the degree to which the two-wire circuit matches the compromise network. It is measured in two separate parts of the voice band: between 200 and 500 Hz, and between 2500 and 3200 Hz. The method used is to introduce gain between the receiving and transmitting connections of the hybrid, thru a filter which passes only the lower or the higher band of frequencies. The gain is increased until sustained oscillation (singing) occurs. The amount of gain is the singing point, and is roughly equivalent to the singing return loss. The lowest value on the return loss versus frequency trace of the Model 420 is a good indication of the probable frequency and value of the singing point. Thus, one setup and one measurement with Model 420 gives all of the values needed for both echo return loss and singing point. The values may be recorded with a camera for later analysis.

6.41 Some typical requirements for echo return loss and singing point, as given by various sources, are:

Circuit Measured	Echo Return Loss (dB)		Singing Point (dB)	
	Ave	Min	Ave	Min
Class 5 Switching System Average Overall Subscriber Lines	11	8	6	4
First-Level 2-Wire Office:				
Trunk-to-Trunk	27	25	20	16
Trunk-to-Station Line (Station Off Hook)	15	9	10	6
Main PBX:				
Trunk-to-Station (900Ω at Station)	24	20	18	14
Trunk-to-Station (Station Off Hook)	15	9	8	6

K. Noise Measurements (Noise Option)

6.42 An ordinary meter of the d'Arsonval or taut-band type usually responds to noise voltages with very erratic fluctuation of the meter pointer, making it difficult

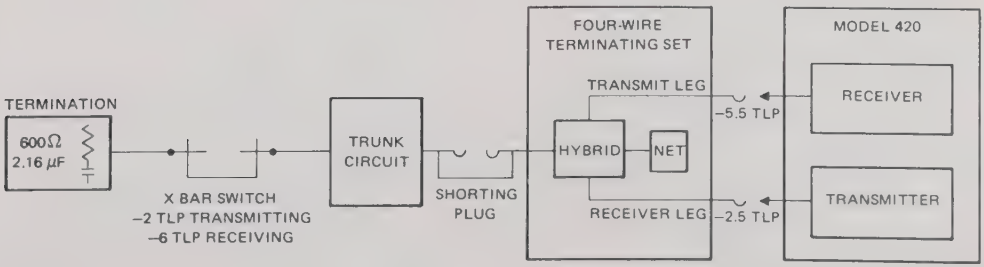


Figure 21. Typical Setup for Four-Wire Return Loss Measurement Machine Switching Toll Office on a 4 dB Toll Circuit

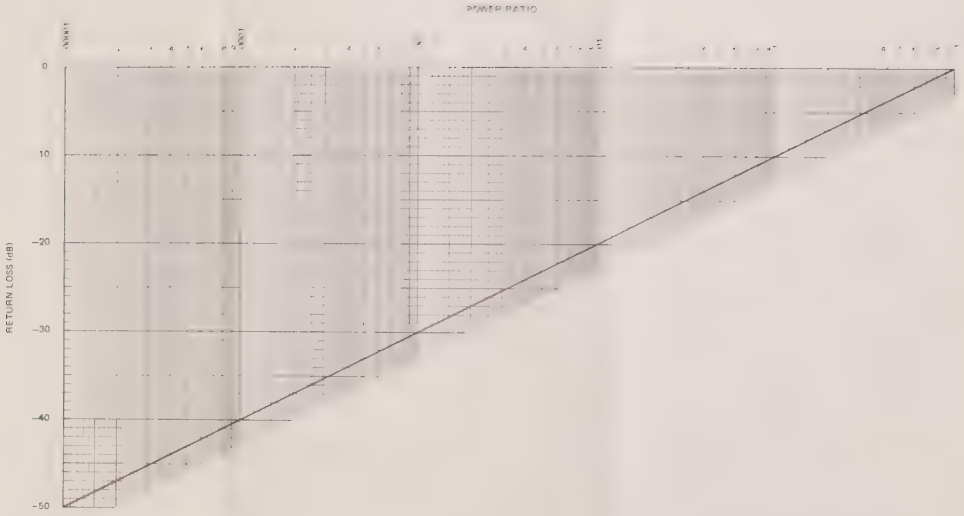


Figure 22. Return Loss Versus Power Ratio

to estimate the average noise power. To simplify the procedure using this type of meter, a specification has been developed for damping the meter so that it averages noise power over a period of time. With its RESPONSE switch in the DAMPED position, the Model 420 receiver gives an indication that is equivalent to the damped meter in the Western Electric 3-A or 3-C Noise Measuring Set. To observe the undamped reading, throw the RESPONSE switch to NORMAL position. In this position, the trace usually will be a vertical line. The ends of this line indicate the extremes of the fluctuations; the average noise power is near the center of the brightest part of the vertical line.

6.43 Connect a telephone receiver to the NOISE MONITOR jack to listen to the noise. The sound of the noise will help to identify its nature and source. If the noise level exceeds about 50 dBrn and contains discrete tones, you may be able to measure the frequencies and their levels by setting up the receiver to measure received level. The measured level will help to shoot trouble, but is not readily converted to a weighted noise value and is not to be compared with requirements.

6.44 For most measurements, set the NOISE FILTER switch to C. This switches in the filter for C-message weighting. Other standard weighting filters in the set are 3 kHz flat and 15 kHz flat. Either of these may be switched into the measuring circuit as required.

6.45 Limits for noise on telephone circuits are usually given in terms of dB above reference noise referred to the 0 TLP. Some typical limits for noise on telephone circuits, as given by various sources, are as follows:

Length of Circuit (Miles)	Circuit Noise Limits (dBrnC0)	
	Design Objective	Maintenance Limits
Less than 50	31	44
50 - 100	34	44
100 - 400	37	44
400 - 1000	41	50
1000 - 1500	43	50
1500 - 2500	45	50
2500 - 4000	47	50
4000 - 6000	48	50

7. REFERENCES

7.01 In this manual are some typical requirements in terms of the pointer-on-scale readings and methods of applying these requirements to the graphic display of the Model 420. The theory underlying the tests, and additional background, are contained in the books and technical papers listed in Table A.

7.02 Table B lists selected Bell System Practices which deal with transmission measurements for which the Model 420 Transmission Level Test Set is particularly useful.

TABLE A

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TABLE B

BELL SYSTEM PRACTICES

B.S.P. No.	Title
300-300-503	Completion Tests of Exchange Area Cables —— Testing
330-450-100	Fault Location Using VF Sweep Tests —— General Theory
330-450-101	Fault Location Using VF Sweep Tests —— Trunk Cable Parts
330-450-102	Fault Location Using VF Sweep Tests —— Subscriber Cable Pairs
330-450-507	Fault Location Using VF Sweep Tests —— Detailed Analysis
330-300-901PT	Toll and Trunk Cables, Acceptance Tests —— Expected Test Results (Published by the Pacific Tel. and Tel. Co., San Francisco)

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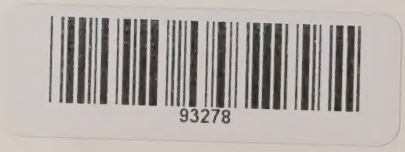
MA35662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